This is a digital copy of a book that was preserved for generations on library shelves before it was carefully scanned by Google as part of a project to make the world's books discoverable online.

It has survived long enough for the copyright to expire and the book to enter the public domain. A public domain book is one that was never subject to copyright or whose legal copyright term has expired. Whether a book is in the public domain may vary country to country. Public domain books are our gateways to the past, representing a wealth of history, culture and knowledge that's often difficult to discover.

Marks, notations and other marginalia present in the original volume will appear in this file - a reminder of this book's long journey from the publisher to a library and finally to you.

Usage guidelines

Google is proud to partner with libraries to digitize public domain materials and make them widely accessible. Public domain books belong to the public and we are merely their custodians. Nevertheless, this work is expensive, so in order to keep providing this resource, we have taken steps to prevent abuse by commercial parties, including placing technical restrictions on automated querying.

We also ask that you:

+ *Make non-commercial use of the files* We designed Google Book Search for use by individuals, and we request that you use these files for personal, non-commercial purposes.

+ *Refrain from automated querying* Do not send automated queries of any sort to Google's system: If you are conducting research on machine translation, optical character recognition or other areas where access to a large amount of text is helpful, please contact us. We encourage the use of public domain materials for these purposes and may be able to help.

+ *Maintain attribution* The Google "watermark" you see on each file is essential for informing people about this project and helping them find additional materials through Google Book Search. Please do not remove it.

+ *Keep it legal* Whatever your use, remember that you are responsible for ensuring that what you are doing is legal. Do not assume that just because we believe a book is in the public domain for users in the United States, that the work is also in the public domain for users in other countries. Whether a book is still in copyright varies from country to country, and we can't offer guidance on whether any specific use of any specific book is allowed. Please do not assume that a book's appearance in Google Book Search means it can be used in any manner anywhere in the world. Copyright infringement liability can be quite severe.

About Google Book Search

Google's mission is to organize the world's information and to make it universally accessible and useful. Google Book Search helps readers discover the world's books while helping authors and publishers reach new audiences. You can search through the full text of this book on the web at `http://books.google.com/`

Library
of the
University of Wisconsin

DEPARTMENT OF THE NAVY
BUREAU OF STEAM ENGINEERING

REPORT

OF THE

U. S. NAVAL "LIQUID FUEL" BOARD

OF TESTS CONDUCTED ON THE

HOHENSTEIN WATER TUBE BOILER,

SHOWING THE

RELATIVE EVAPORATIVE EFFICIENCIES OF COAL AND LIQUID FUEL UNDER FORCED AND NATURAL DRAFT CONDITIONS

AS DETERMINED BY

AN EXTENDED SERIES OF TESTS

MADE UNDER THE DIRECTION OF

Rear-Admiral GEORGE W. MELVILLE,
Engineer-in-Chief, U. S. Navy.

John R. Edwards, Commander, U. S. N.,
Wythe M. Parks, Lieutenant-Commander, U. S. N., *Board.*
Frank H. Bailey, Lieutenant-Commander, U. S. N.,

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1904.

5606990

83859
[illegible] 1905
LRPS
·UN3

CONTENTS.

	Page.
Introductory	3
General dimensions of the Hohenstein boiler used for conducting the comparative tests	4
Special characteristics of the experimental boiler	5
General arrangement of the auxiliaries of the experimental plant	7
Manner in which the weight of coal, water, and refuse was ascertained	8
Actual weight of water contained in boiler	9
Character of the steam evaporated	10
Character of the coal used	10
The composition and temperature of flue gases	11
Arrangement of pressure gauges	11
Manner of determining quantity of air used	13
Importance of installing draft gauges at various points between ash pan and base of stack	13
The coal tests; data secured during coal tests	13
Tables giving the records of seventeen coal tests under the experimental boiler	16-49
Summary of the seventeen tests under coal	50-53
Increased evaporative capacity should be demanded of water-tube boilers of the straight-tube type	54
The problem of the water-tube boiler	54
The oil tests	58
The experimental plant thoroughly overhauled before commencing liquid-fuel tests	58
General description of the experimental plant when burning oil fuel	58
Method of weighing oil used	61
Character of the oil used	62
Conditions between the combustion chamber and smokestack	62
Endurance test of one hundred and sixteen hours	66
Chemical composition of the oil used during tests compared with the crude product	68
Analysis of Beaumont oil used by liquid-fuel board as determined by chemist, navy-yard, New York	68
Analysis of California oil used by liquid-fuel board as determined by chemist, navy-yard, New York	69
Analysis of residuum mixture of California and Texas oils	69
The Hayes hydrocarbon burner	70
The Oil City Boiler Works burner using steam for atomizing the oil	74
The F. M. Reed combined air and steam burner	76
The "Harvey" system	78
The "Branch" burner equipment	80
"Advance" design of oil burner	82
Santa Fe or "Booth" type of oil burner	84

Page.
Summary of Santa Fe tests 88
McDonald fluid-fuel burner 91
The "W. N. Best" oil burner 91
Summary of tests of the "Best" burner 95
Oil City Boiler Works burner 95
Comparison of results secured with burners using Texas and California oils ... 97
General plan of oil tests 102
Tabular results of sixty-nine oil-burning tests 104–241
Summary of the sixty-nine oil tests 242–257
Tests of centrifugal burners 258
Conclusions as to centrifugal burners 264
Proposed centrifugal burner 265
Supplementary experiments conducted 267
Extent of research work and investigation conducted by the board 272
The oil-fuel installation of the steamship *Mariposa* 272
The voyage of S. S. *Mariposa*, using an oil-fuel installation exclusively under her boilers 273
Report on oil-burning fittings of S. S. *Mariposa* 273
Description of the *Mariposa* 273
Trial trips of the *Mariposa* 279
Lieut. Ward Winchell's report of the *Mariposa's* voyages 280
Summary of results of oil burning on S. S. *Mariposa* 286
Abstract of results of oil burning on S. S. *Alameda* 290
Oil-fuel installation on steamships *Nebraskan* and *Nevadan* 294
Summary of passages of oil-burning vessels *Nebraskan* and *Nevadan*, of American-Hawaiian Line 298
Description of S. S. *Nebraskan* installation 300
Similarity of conditions attending the oil-fuel installations for locomotive and torpedo-boat work 308
Hoosac Tunnel locomotive installations 308
Mechanics of combustion as specially relating to using liquid fuel 313
Mechanical burners, possibility of avoidance of use of either steam or air as atomizing medium 320
Oil fuel tests on board the steamer *Tebe* 328
Results of trials with Korting burners with induced draft on marine boilers ... 334
The oil-fuel installation of the S. S. *City of Everett* 336
Classification of oil burners 338–358
Orificial spraying 359
Nonsuccess of apparatus depending on gasification of oil 364
Necessity of efficiently installing all auxiliary appliances 366
Separation of water 369
Heaters for oil 369
Feed tanks for burners 371
Oil-pressure regulators 371
Oil-cargo pumps 372
Tank ventilation 372
Air compressors 373
Furnace construction 373
Furnace forms for Scotch marine boilers 375
Furnace forms for water-tube boilers 379
Special types of furnaces 383
Confirmatory evidence as to the reliability of the data secured by the liquid-fuel board 385

Page.
Necessity of permitting unofficial or preliminary trials 388
Sources of the oil supply used for experimental purposes 389
Relative value of coal and oil as a fuel 390
Table of oil prices 392
Structural, transportation, and supply features of the oil-fuel problem, great bars to the use of such fuel on board naval vessels 394
The smoke nuisance 398
Scope and detailed management of experiments open to the inspection of technical marine experts 402
Necessity of rapidly and closely regulating the admission of air requisite for combustion 403
Influence of hygrometric condition of the atmosphere regarding efficiency and capacity 404
Oil fuel requires the highest character of installation 405
Thermal efficiency not increased by the use of steam 407
Naval research should be conducted entirely by persons within the Navy 407
The world's relative production of coal and crude petroleum 409
Tables of world's coal production 410
Tables of crude petroleum production 411
Available oil production of the United States 416
Economical advantages of an oil-fuel installation 417
Efficiency and endurance of the Hohenstein boiler 419
Question of fuel supply only one remove in importance from that of food supply as regards our actual naval strength 422
Oil-fuel installation desirable in one of the Pacific coast monitors 423
Oil installation likewise desirable in several torpedo boats 423
Tests conducted exclusively by naval personnel 424
Valuable services rendered by assistants 425
Experimental engineering research work of great value to junior officers 426
Final conclusions derived from a comparative study of the coal and oil tests 428

REPORT OF THE "HOHENSTEIN BOILER" AND "LIQUID FUEL" BOARDS.

INTRODUCTORY.

While the extended series of tests for determining the relative value of coal and liquid fuel for naval purposes were conducted and completed during the incumbency of Rear-Admiral George W. Melville, as Chief of the Bureau of Steam Engineering, the preparation of the report has been in progress since the accession to office of Rear-Admiral C. W. Rae as Engineer in Chief of the Navy.

As the Bureau of Steam Engineering has been exceedingly desirous of having the report embrace complete and reliable information as to the development of oil fuel installations, the Fuel Board therefore made special effort to note the progress made to date and thus to make the report of value to all interested in the use of liquid fuel for either manufacturing, marine, or naval purposes.

Special attention is called to the fact that the cost involved in the installation and operation of the experimental boiler plant, combined with the direct and indirect expenditure incurred by individuals and the Navy Department in conducting the extended series of tests probably represents the largest outlay ever heretofore incurred by either private, corporate, or official interests in the thorough investigation of the important problem of determining the possible future field for the use of crude petroleum as a fuel.

Navy Department,
Washington, D. C., August 1, 1904.

Department of the Navy,
Bureau of Steam Engineering.

Sir: The undersigned, appointed a board to conduct an extended series of tests to determine the merits of the Hohenstein water-tube boiler as a steam generator of approved type for ships of war, and for investigating the relative value of coal and oil as a fuel for naval purposes, submits the following report:

The water-tube boiler used during these tests was of the straight large tube type, and was built to conform to the requirements of weight, capacity, and space occupied by one unit of the boiler installation of cruisers of the *Denver* class. Each unit of the boiler installation of vessels of the *Denver* class is required under forced draft of 1-inch water pressure, and under 275 pounds steam pressure, to evaporate 12,000 pounds of water per hour under actual steaming conditions. On the basis of 16 pounds of water per indicated horsepower per hour there would thus be developed for main engines and circulating pumps about 15 I. H. P. per hour per square foot of grate surface, a requirement that is not exceeded by any other installation of straight large tube type of boiler in the United States Navy. When using forced draft during both coal and oil tests this designed capacity was greatly and repeatedly exceeded without detriment to the tubes and drums, and therefore speaks well for the efficiency and endurance of the design and workmanship of the boiler under test.

As comparative data is of the greatest practical value in affording information or determining results, it should be stated that coal was the fuel used from April 23, 1901, to January 11, 1902, when determining the evaporative efficiency, capacity, reliability, and endurance of the design of the experimental boiler.

A careful study of the data and summary of the coal and oil tests ought thus to furnish comparative and reliable information, and enable marine-boiler designers, as well as all having a direct interest in the boiler problem, to note for themselves the relative advantages and disadvantages of the two kinds of fuel when tested under as nearly similar conditions as could possibly be secured.

GENERAL DIMENSIONS OF THE HOHENSTEIN BOILER USED FOR CONDUCTING THE COMPARATIVE TESTS.

Drums.—There are six steam drums, forming a double hollow parallelopipedon. There is a front drum, 24 inches in diameter; a rear drum, 24 inches in diameter, and four connecting drums, each 16 inches in diameter. There is also a lower rear mud drum 24 inches in diameter.

Tubes.—There are sixteen 4-inch tubes 7 feet long, three hundred and eighty-four 2-inch tubes 9 feet long, and fifteen 5-inch downtake tubes, which are connected to the rear steam drum and to the mud drum.

Heating and grate surface.—There are 2,130 square feet of heating surface and 50.14 square feet of grate surface. Ratio of heating surface to grate surface, 42.5 to 1.

Floor space.—Nine feet wide, 10 feet 11¼ inches deep.

Height over all.—Twelve feet 6¾ inches.

Volumes.—Water at steaming level, 142 cubic feet; steam space, 50 cubic feet; furnace volume above grate bars, 121.14 cubic feet.

Weights.—Boiler and fittings, excluding uptake and smoke pipe:

	Pounds.
With water	54,127
Without water	46,668

Per square foot of heating surface at steaming level and at 275 pounds pressure:

	Pounds.
With water	25.4
Without water	21.8
Water per square foot grate surface	1,080

Ratios.—Area of grate to area of air spaces (average for all the tests with coal), 1 to 0.57.

Measurements of smokestack.—Height of stack above the grate, 70 feet; cross section of smokestack, 8.73 square feet; ratio of smokepipe area to grate area, 1 to 5.75.

SPECIAL CHARACTERISTICS OF THE EXPERIMENTAL BOILER.

Drums.—The arrangement of the drums provides for a large body of water within them, thus affording a marked steadiness of water level. The design of these drums likewise secures a large steam-liberating area, as well as a space above the water level sufficient to insure unusual dryness of steam.

Arrangement of tubes.—A most noteworthy feature of the boiler is the arrangement of the tubes in pairs, in such a way that each tube is free to expand independently of other tubes, thus effectually preventing longitudinal stresses. The tubes, instead of being expanded into rigid headers at both ends, are so arranged that at least one end of each tube is expanded into a junction box.

There are two sizes of tubes. Sixteen of these tubes are 4 inches in diameter, and are the ones which are subjected to the greatest heat and strain. These large tubes are expanded into a mud drum at the rear end, the drum being of sufficient size, however, to permit a man to enter either to make examination or repairs. It requires but the removal of a single plug either to examine or to clean any large tube.

There are 384 2-inch tubes whose ends are expanded into junction boxes. The removal of these tubes was easily effected, a test of the time and difficulty attending this operation having been exacted during the experiments by the Board.

There are fifteen 5-inch downcast tubes. The comparative sectional areas of generating tubes and of downcasts is such that the carrying capacity of the latter is more than ample to supply the generating tubes. There is room between the downcast tubes and the rear set of junction boxes for a man to enter to remove plugs and cut out the

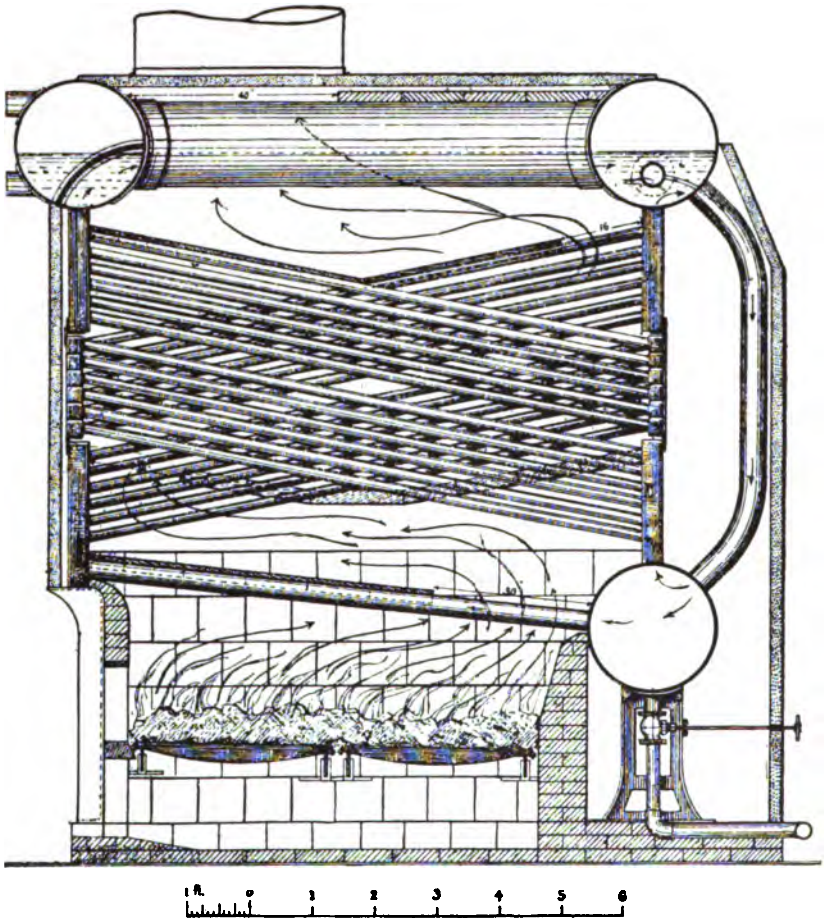


FIG. 1.—The Hohenstein experimental boiler used in the naval tests, arranged for coal burning.

tubes, thus permitting for naval construction the downcast tubes to be placed quite close to the athwartship bulkheads.

Junction boxes.—In each element or cycle of tube arrangement there is but one junction box to impair the flow of circulation. As it will undoubtedly be found that in every form of straight water-tube boiler there will be buckling of the tubes in case some provision is not made for allowing for expansion, the introduction of a single junction box should have important advantages. Such a junction box is free to accommodate itself to any irregularities due to the expansion or contraction of the tubes. It was observed during one of the fuel-oil tests that when the front casing was removed and fires lighted under the cold boiler that the displacement of one of the lower front junction boxes did not exceed one-eighth of an inch in the vertical plane.

Efficiency of the composition plugs.—Opposite every tube end, composition plugs have been fitted in the junction boxes. These plugs are of two sizes, 2⅝ inches and 4½ inches in diameter, with, respectively, 11½ and 8 threads per inch. The threads are lubricated with graphite. Some of the plugs are made with tapering threads, and depend for tightness on these threads alone. It was thought that the relative high coefficient of expansion of the composition plug would cause the plug to be tight under steam, and easily removable when cold. It was found necessary, however, to cut out some of these plugs when it was desired to examine the tube, thus showing that the composition when expanded had taken a permanent set, somewhat resembling cast iron in this respect.

The plugs with parallel threads were packed, under the narrow flange at the end, with Merwath gaskets. These gaskets consist of concentric copper and lead rings soldered together. The plugs secured in this way were easily removed and found to be tight under pressure.

Character of the circulation.—Attention is called to the fact that the entire down flow of circulation takes place within the 5-inch vertical tubes (see Fig. 1*a*), which are located in a comparatively cool place, while, on the other hand, there is invariably an upward trend to the circulation in all horizontal tubes and headers exposed to the hot gases. It is highly improbable that there are reverse currents at any part of the water circuit. The feed water is introduced at the top of the downtake tubes, which is obviously the best possible place as regards influence on the circulation. At the same time the head due the velocity of the feed water is augmented by means of injector nozzles pointing in the direction of the flow.

GENERAL ARRANGEMENT OF THE AUXILIARIES OF THE EXPERIMENTAL PLANT.

Air-tight steel structure.—The boiler was erected in a steel structure built especially for these tests. The following are the general dimensions of this air-tight building: Floor space, 16 feet by 24, and height, 14 feet. There was an air lock for entrance and exit during forced-draft trials. There were seven windows fitted that could be opened during natural-draft trials.

Compressors.—There was a Root blower (No. 3 size) driven by a direct connected engine 8 by 9 inches which was capable of delivering 8 cubic feet of free air per revolution, at pressures ranging from ¾ pounds to 5 pounds per square inch. There was also a Rand air compressor of the very latest design capable of giving pressures up to a hundred pounds per square inch. The following are some of the dimensions of this blower:

	Inches.
Steam cylinder:	
Diameter	10
Stroke	14
Compressor:	
H. P	10
L. P.	16

Pumps.—There was installed a Davidson suction pump, a Snow high-pressure feed pump, and several Blake pumps. It was exceedingly unfortunate that a larger size feed pump was not installed, since the evaporative capacity of the boiler under test exceeded the limit of the feed supply that could be furnished by the Snow pump.

Blowing engine.—There was a direct connected blowing engine and fan. The fan had an impeller 72 inches in diameter and a discharge duct 20 inches by 42 inches, which led to the fire room and terminated in a box placed so as to direct the air current toward the ceiling.

Measuring instruments.—Standard scales, test gauges, and other instruments of precision were used so that the most accurate data possible could be collected.

MANNER IN WHICH THE WEIGHT OF COAL, WATER, AND REFUSE WAS ASCERTAINED.

Feed water.—The feed water was generally muddy. The supply was drawn from the Potomac River through a suction pipe that ran out to the end of a dock. No test was either delayed or stopped solely on account of the character of the feed, and there were times when an unusually heavy quantity of mud was in this feed supply.

The feed water was weighed in two circular tanks holding respectively 1,046 and 1,047 pounds of water each, and resting on 1,500-pound Howe scales. These scales had been tested by the city's sealer of weights and measures. The scales and weighing tanks were on a platform above the feed tank. The weight of each tank when filled was recorded, and then the water was allowed to flow into the feed tank as needed. As soon as the weighing tank was emptied the weight was again taken and the time noted. The feed tank was provided with a graduated water-level gauge. The height of water by this gauge was noted at the moment of beginning the test, and at the end of each hour it was again brought to the same level. The feed tank had a steam coil for heating the water. Wide variations in the temperature were easily avoided by keeping the water level in the tank fairly constant.

In some of the forced-draft trials the weighing tanks had to be filled, weighed, and emptied with such rapidity, owing to their insufficient size, that the above method of catching the weight at the end of each hour could not be used. The weighing tanks were accordingly each fitted with a water-level gauge graduated to 5 pounds, by the aid of which the weight within 5 pounds could be caught at any moment without interfering with the rapid manipulation of the tanks. The temperature of the feed water was taken at an elbow of the feed pipe between the pump and the boiler.

ACTUAL WEIGHT OF WATER CONTAINED IN BOILER.

The following determination was made of the actual weight of water contained in the boiler at a temperature of 56° F. and at different gauge-glass readings, the correct steaming level being at 1 inch:

Height of water in gauge.	Total weight of water.	Difference.	Area of water level.
	Pounds.	*Pounds.*	*Sq. feet.*
0	8,588		
1 inch	8,869	281	52.2
2 inches	9,235	366	70.5
3 inches	9,648	413	79.6
4 inches	10,033	385	74.2
5 inches	10,405	372	71.7

Coal.—The coal was weighed in sheet-metal cans or bags, the method being to adjust each can or bag to a uniform weight of 220 pounds or 130 pounds while on the scales, and then keep tally of the number passed into the fireroom. Beginning with the seventh test, the coal account was balanced at the end of each hour by estimating and deducting the weight of coal lying at the moment on the fireroom floor.

Refuse.—The ashes and refuse were weighed in sheet-metal cans as they accumulated, and the weight of sweepings from tubes and baffles was carefully ascertained. By reason of the coal tests being limited to periods of short duration there was practically no cleaning of fires, and thus the percentage of refuse is much smaller than would occur under actual seagoing conditions.

CHARACTER OF THE STEAM EVAPORATED.

The quality of the steam was determined by means of a Barrus throttling calorimeter, which drew steam from the main steam pipe at a point 8 inches in front of the boiler. The sampling nozzle consisted of a half-inch pipe reaching nearly across the steam pipe in a horizontal diameter. This pipe had four rows of perforations extending the length of the diameter of the inside of the steam pipe—say, for 1¼ inches at each end. An extra calorimeter was fitted and readings were taken from both calorimeters throughout the series of trials, except when, as once occurred, the extra calorimeter got out of order by the lodgment of black scale in its throttling orifice.

CHARACTER OF THE COAL USED.

From each can or bag of coal that was brought into the fireroom, a specimen was taken and collected in a box, so that there could be forwarded for analysis a fair sample of the fuel used.

The following table gives the result of analyses of samples of each lot of coal. The analyses were made by the chemist at the New York Navy-Yard:

	Pocahontas coal, run of mine.		New River coal, run of mine.	Pocahontas coal, hand picked and screened.
	Fuel burned in boiler test No.—			
	1, 2, 3.	4, 5, 6.	7, 8, 9.	10 to 17.
PROXIMATE ANALYSIS.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Fixed carbon	73.30	75.78	72.99	76.81
Volatile matter	17.61	19.53	21.79	19.62
Moisture	.49	.79	.49	.73
Ash	8.60	3.90	4.73	2.84
	100.00	100.00	100.00	100.00
Sulphur, separately determined	.48	.71	.46	.82
ULTIMATE ANALYSIS.				
Carbon	82.26	84.96	83.60	85.94
Hydrogen	3.89	4.07	4.85	4.45
Oxygen	4.12	5.46	4.87	4.50
Nitrogen	.64	.90	1.41	1.14
Sulphur	.49	.71	.46	.82
Ash	8.60	3.90	4.81	3.15
	100.00	100.00	100.00	100.00
CALORIFIC VALUE (B. T. U.'S PER POUND).				
Coal	14,067	14,534	14,841	14,992
Combustible	15,391	15,124	15,684	15,475

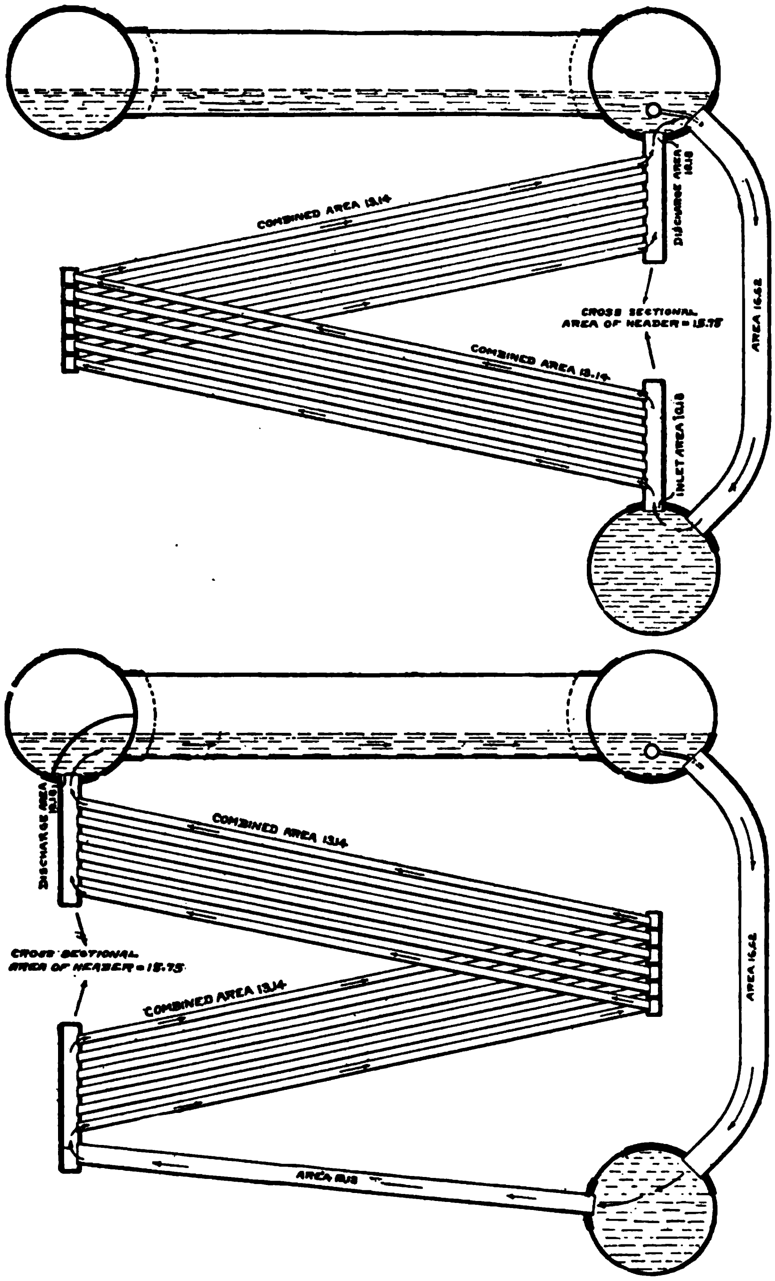


FIG. 1*a*.—Circulatory system of the Hohenstein naval test boiler.

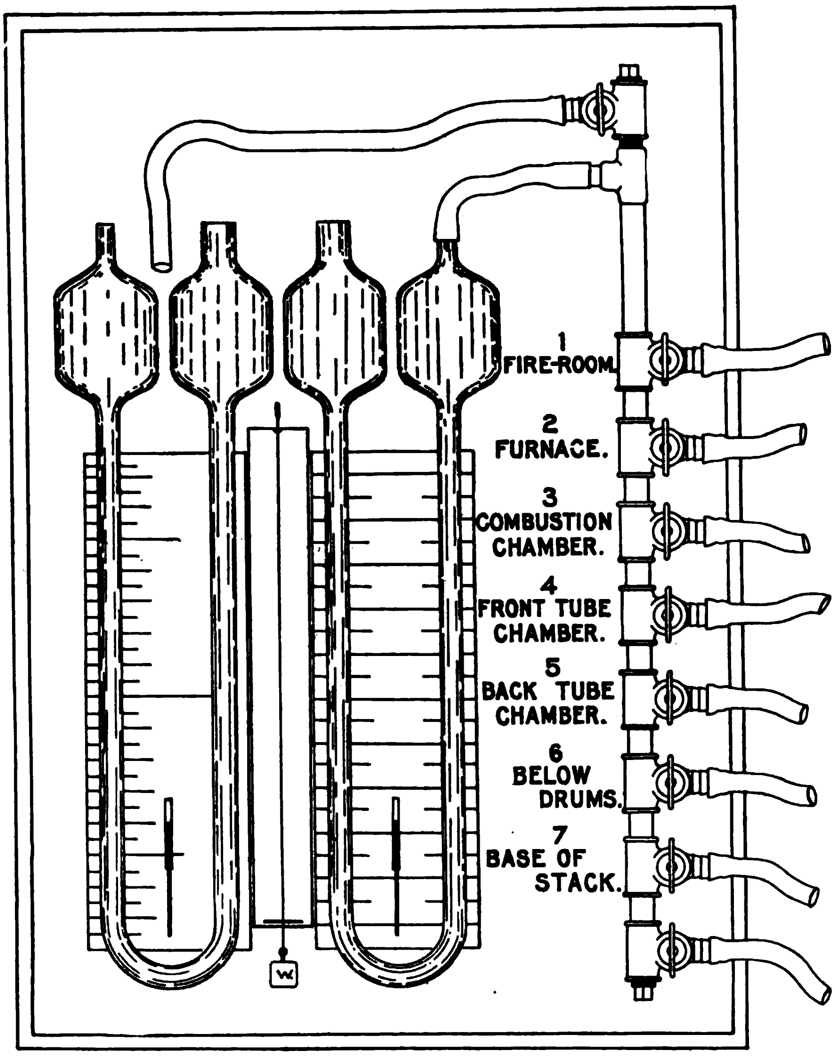


FIG. 1b.—Draft gage installation for boiler tests.

THE COMPOSITION AND TEMPERATURE OF FLUE GASES.

Samples of the flue gas were drawn from the smokestack by means of an aspirator improvised from two half-gallon bottles. The sampling tube was one-half inch diameter and extended to the center of the stack, the inner end being nearly closed and the sides being perforated with one-eighth inch holes, spaced 4 inches apart. The aspirator, charged with gas, was carried to a neighboring building, where the sample was analyzed by the aid of an Orsat apparatus.

The temperatures at the base of the stack and the samples of flue gas were taken above the roof at a point about 5 feet from the nearest heating surface of the boiler, measured along the path of flow of the gases. In the natural-draft trials the temperatures were taken with a mercury-nitrogen pyrometer, and attempts were made to do the same in the forced-draft trials. Momentary flaming in the stack, however, caused so many breakages of glass bulbs that reliance had finally to be placed on a Brown quick-reading pyrometer, the readings of which were, however, checked as well as could be by the melting points of zinc, aluminum, and copper.

Exceptional care was taken in the collection of all data relating to the flue gases, in order that some definite information might be secured as to the temperature of gases at various points as well as to determine the best means of installing baffling. The increased efficiency of the water-tube boiler will undoubtedly be secured by changes in baffling, whereby the flow of gases will be more greatly impeded and the removal of soot more quickly effected.

ARRANGEMENT OF PRESSURE GAUGES.

The several air pressure and steam gauges were placed near each other on the wall of the steel structure, and particular care was taken in the fitting of necessary pipe connections.

The following sketch (1*b*) shows the arrangement designed by the board to quickly read the air pressure at any point of the boiler between the ash-pit and the base of the stack. In the bent tube at the left, liquids of different densities were introduced so that light variations in pressures could be quickly detected. As compared with the bent tube at the right, the tube at the left showed variations in the pressure magnified ten times.

The apparatus consists of a pair of U-shaped glass tubes, with expansions formed at the top of each tube, for the purpose of augmenting the surface of the liquid in the tubes exposed to the action of the gas pressures. The successive introduction of the pressure to the top of the liquid in one tube was provided for by the use of a rubber-tube connection to the top of what might be regarded as a gas switchboard or gas manifold. By turning the proper gas cock the pressure could

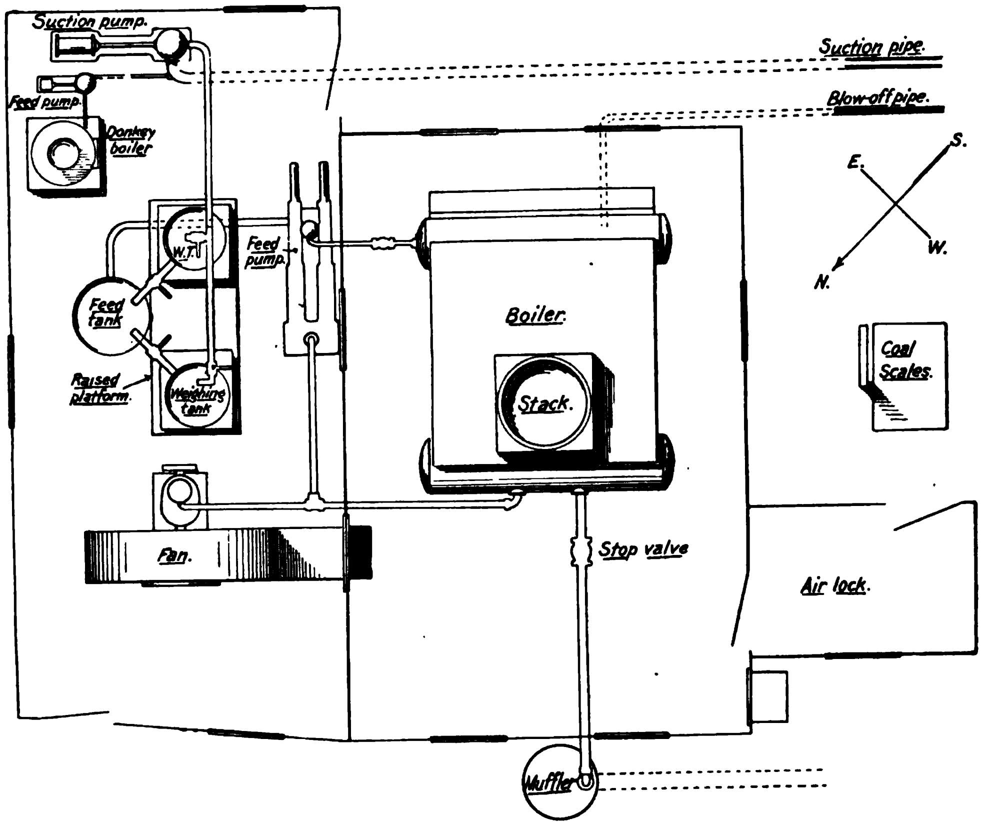


FIG. 2.—Arrangement of Hohenstein's experimental boiler plant for coal-burning tests.

be brought from any of the points on the boiler, as indicated by the lettered name plate, and its effect brought to bear on the surface of the liquid in one of the bulbs. The U tubes were filled with nonmixing liquids of different densities and different colors, so arranged that the line of demarcation between the two liquids would come approximately to the middle of the length of each limit of the U. Before beginning a reading the graduated scale at the back of the tubes was brought to the common zero by the touch of a lever provided in a slot at the bottom of the scale. By the use of this apparatus the determination of draft pressures for each of the seven points were accurately and rapidly read.

The steam gauges were 3 feet lower than the water level in the boiler. A deduction of 1½ pounds from the observed steam pressures was therefore made in working up the results. The steam was blown off into the atmosphere, the pressure being controlled by a hand operated stop valve.

MANNER OF DETERMINING QUANTITY OF AIR USED.

In the accompanying tables of the individual trials the "pounds of air per pound of carbon" was calculated by the approximate formula,

$$\frac{11.55\ (CO_2+O+\frac{1}{2}CO)}{CO_2+CO}$$

which takes no account of the air consumed in burning hydrogen. In the table of summaries the weight of dry gas per pound of carbon is calculated by the accurate formula as there given.

IMPORTANCE OF INSTALLING DRAFT GAUGES AT VARIOUS POINTS BETWEEN ASH PAN AND BASE OF STACK.

By varying the connections of the draft gauges during the early trials it was found that the draft was seriously interfered with by the resistance of the uptake. The uptake was accordingly increased in size for the later trials, with the result that the boiler showed a greater capacity and the fireroom temperature was much lower. With this change there was no further trouble as there had been previously, with the burning of grate bars. The variation of draft pressure within the boiler, together with the improvement that resulted from the change just alluded to, is shown diagrammatically in fig. 3.

DATA SECURED DURING COAL TESTS.

All the data recorded during the coal or oil tests was taken by draftsmen attached to the Bureau of Steam Engineering or by persons connected with the naval service. No reading of any gauge was recorded by anyone either interested in the experimental boiler or in

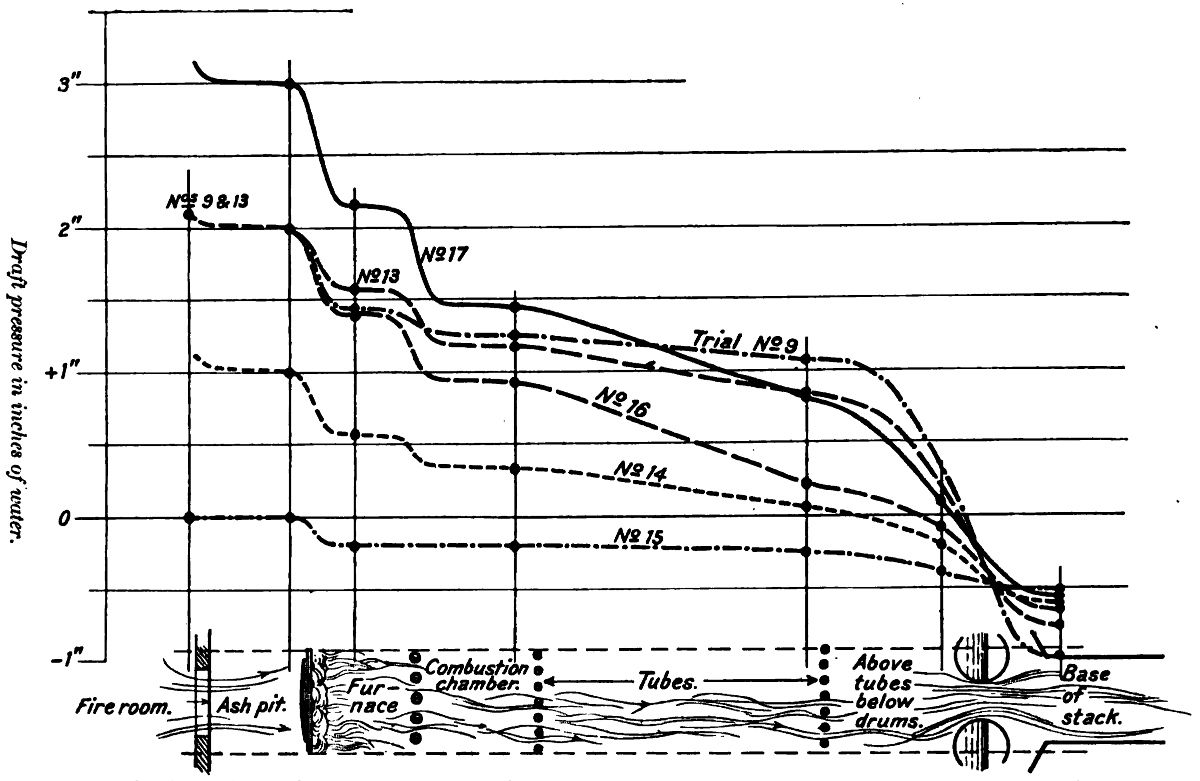


Fig. 3.—Curves showing variation of air pressure within the boiler during certain coal-burning trials. Spots indicate points where measurements were made.

any appendage or auxiliary connected with the plant. There was no effort made nor desire manifested to secure results that would eclipse other records. The primary object was to secure data that would show what might to be obtained in actual service.

The board, therefore, believes that in comparing the data obtained during these experiments with any other recorded data, particular consideration should be given to the fact that during these tests all readings were made by persons who had no interest or purpose in securing specific results. It is believed that if the data recorded be carefully studied there will be conclusive circumstantial evidence adduced to show its reliability.

During some experiments there were as many as ten persons taking data, and therefore it was possible to check the readings of the gauges sufficiently often to feel assured that reliable information was being secured. The board worked on the principle that any recorded information would be valueless unless reliable, and therefore neither trouble nor expense was spared in making arrangements for securing correct information.

No. 1.—*Test of Hohenstein water-tube marine boiler, April 23, 1901.*

[Eight hours' duration with natural draft, using coal as a fuel.]

Time.	Steam pressure by gauge.	Temperature of feed water.	Calorimeter.			Temperature.		
			Higher temperature.	Lower temperature.	Quality of steam.	Outside air.	Air in fire room.	Gases at base of stack.
	Lbs.	° *F.*	° *F.*	° *F.*		° *F.*	° *F.*	° *F.*
9.30 a. m....	245	130	....	....	....	52	....	485
9.45 a. m....	270	180	410	330	0.996	....	87	570
10 a. m	270	170	408	320	.991	50	87	602
10.15 a. m...	270	170	406	310	.985	....	87	720
10.30 a. m...	270	155	406	310	.985	55	89	(a)
10.45 a. m...	270	170	406	314	.988	....	93	(a)
11 a. m	270	160	406	316	.989	53	93	(a)
11.15 a. m...	272	150	404	308	.984	....	91	(a)
11.30 a. m...	270	170	404	310	.986	54	89	(a)
11.45 a. m...	270	150	404	262	.957	....	90	(a)
12 m	270	150	404	310	.986	55	88	(a)
12.15 p. m ..	270	130	404	309	.986	....	88	(a)
12.30 p. m ..	270	140	406	308	.986	55	89	(a)
12.45 p. m ..	268	120	404	309	.986	....	94	(a)
1 p. m	268	130	406	309	.986	56	94	(a)
1.15 p. m ...	265	160	409	310	.984	....	94	(a)
1.30 p. m ...	265	160	404	300	.980	62	94	(a)
1.45 p. m ...	265	150	404	308	.986	....	97	(a)
2 p. m	265	125	404	316	.984	61	97	(a)
2.15 p. m ...	260	120	404	310	.986	....	96	(a)
2.30 p. m ...	260	135	404	310	.986	59	96	(a)
2.45 p. m ...	260	125	404	318	.986	....	97	(a)
3 p. m	260	150	404	310	.986	62	100	(a)
3.15 p. m ...	265	150	404	310	.986	....	101	(a)
3.30 p. m ...	265	110	404	302	.981	61	101	(a)
3.45 p. m ...	260	130	404	268	.961	....	101	(a)
4 p. m	265	140	404	224	.936	61	102	(a)
4.15 p. m ...	260	130	404	310	.986	....	101	(a)
4.30 p. m ...	265	135	404	264	.959	60	100	(a)
4.45 p. m ...	265	130	404	252	.952	....	86	(a)
5 p. m	260	135	404	309	.986	59	87	(a)
5.15 p. m ...	265	140	404	308	.986	....	92	(a)
5.30 p. m ...	265	160	404	304	.984	59	100	(a)
Average	265.4	144	....	....	.980	57.3	93.8	594

[a] Pyrometer out of order.

State of weather, clear.
Barometer at noon, 30.02 inches.
Kind of fuel, Pocahontas coal, run of mine.
Wood burned in starting fires, 350 pounds.
Coal burned in starting fires, 2,400 pounds.
Coal burned during test, 9,720 pounds.
Ashes before beginning test, 260 pounds.

No. 1.—*Test of Hohenstein water-tube marine boiler, April 23, 1901.*

[Eight hours' duration with natural draft, using coal as a fuel.]

Time.	Height of water in gauge glass.	Air-pressures in inches of water.		Flue gases.				Water.	
		Ash pit.	Base of stack.	CO_2.	O.	CO.	Dry air per pound carbon.	Fed per hour.	Total weight fed.
	Ins.			*P. ct.*	*P. ct.*	*P. ct.*	*Lbs.*	*Lbs.*	*Lbs.*
9.30 a. m	....	....	—0.30	......	......	......	......	......	......
9.45 a. m	....	—0.05	— .30	......	......	......	......	......	......
10 a. m	4	— .05	— .40	......	......	......	......	......	......
10.15 a. m	4	— .05	— .40	......	......	......	......	......	......
10.30 a. m	4	— .05	— .40	10.4	6.1	2.3	16.1	9,511	9,511
10.45 a. m	3½	— .05	— .50	......	......	......	......	......	......
11 a. m	3	— .05	— .55	......	......	......	......	......	......
11.15 a. m	3	— .05	— .60	......	......	......	......	......	......
11.30 a. m	4	— .05	— .55	9.4	7.1	2.2	17.5	9,218	18,729
11.45 a. m	4	— .05	— .50	......	......	......	......	......	......
12 m	4	— .05	— .50	......	......	......	......	......	......
12.15 p. m	3	— .05	— .55	......	......	......	......	......	......
12.30 p. m	4	— .05	— .55	10.3	7.2	.8	18.6	9,867	28,596
12.45 p. m	4	— .05	— .50	......	......	......	......	......	......
1 p. m	3	— .05	— .55	......	......	......	......	......	......
1.15 p. m	4	— .05	— .55	......	......	......	......	......	......
1.30 p. m	4	— .05	— .55	9	8.4	1	20.6	9,100	37,696
1.45 p. m	4	— .05	— .55	......	......	......	......	......	......
2 p. m	3½	— .05	— .55	......	......	......	......	......	......
2.15 p. m	4	— .05	— .55	......	......	......	......	......	......
2.30 p. m	4	— .05	— .55	9.6	5.8	1.6	16.9	9,671	47,367
2.45 p. m	4½	— .05	— .55	......	......	......	......	......	......
3 p. m	4½	— .05	— .50	......	......	......	......	......	......
3.15 p. m	5	— .05	— .55	......	......	......	......	......	......
3.30 p. m	5	— .05	— .55	11	5.5	2.1	15.5	9,832	57,199
3.45 p. m	5	— .05	— .55	......	......	......	......	......	......
4 p. m	4½	— .05	— .55	......	......	......	......	......	......
4.15 p. m	4	— .05	— .55	......	......	......	......	......	......
4.30 p. m	5	— .05	— .55	9.3	7.9	1.7	18.9	9,501	66,700
4.45 p. m	4	— .05	— .55	......	......	......	......	......	......
5 p. m	4	— .05	— .55	......	......	......	......	......	......
5.15 p. m	4	— .05	— .55	......	......	......	......	......	......
5.30 p. m	4	— .05	— .55	......	......	......	......	9,279	75,979
Average	....	— .05	— .515	9.85	6.85	1.67	17.7	9,497	......

Ashes during test, 377 pounds.

Refuse, including sweepings from tubes and baffles, 640 pounds.

Per cent of moisture in coal by weighing and drying sample, 0.5.

Firing very poor and irregular. Average interval between firings, 13 minutes. Average interval between rakings, 12 minutes. Average thickness of fire, 12 inches. At 2.30 p. m. only about two-thirds of the grate was in actual use on account of irregular thickness of fire. Average smoke by Ringelmann charts, 2½. Water drawn from mud drum on following day, when allowed to settle in a bottle, left five-eighths inch of sediment in 8 inches depth of water.

No. 2.—*Test of Hohenstein water-tube marine boiler, April 26, 1901.*

[Six hours' duration with forced draft, using coal as a fuel.]

Time.	Steam pressure by gauge.	Temperature of feed water.	Calorimeter.			Temperature.		
			Higher temperature.	Lower temperature.	Quality of steam.	Outside air.	Air in fire-room.	Gases at base of stack.
	Lbs.	° *F.*	° *F.*	° *F.*		° *F.*	° *F.*	° *F.*
10.35 a. m ..	275	120	407	260	0.956	72	102	640
10.45 a. m ..	260	140	396	290	.978	....	....	....
11 a. m	275	138	393	300	.985	....	98	605
11.15 a. m ..	275	138.	398	299	.977	....	....	....
11.30 a. m ..	275	140	398	278	.970	68	113	690
11.45 a. m ..	275	160	398	272	.967	....	....	....
12 m	275	120	399	288	.976	....	116	710
12.15 p. m ..	275	140	398	303	.984	....	....	....
12.30 p. m ..	275	150	399	212	.930	70	119	750
12.45 p. m ..	275	160	399	304	.983	....	....	....
1 p. m	275	130	399	292	.977	....	120	700
1.15 p. m ...	275	130	399	270	.965	....	....	....
1.30 p. m ...	275	130	398	280	.971	70	120	980
1.45 p. m ...	275	130	399	270	.965	....	....	....
2 p. m	275	138	398	216	.934	....	120	725
2.15 p. m ...	275	170	400	270	.965	....	....	....
2.30 p. m ...	275	145	400	264	.961	70	122	1025
2.45 p. m ...	275	165	400	250	.953	....	....	....
3 p. m	275	145	400	307	.986	....	126	805
3.15 p. m ...	275	140	400	305	.985	....	....	....
3.30 p. m ...	275	160	400	290	.976	72	127	720
3.45 p. m ..	275	150	400	284	.973	....	....	....
4 p. m	275	160	399	276	.968	....	126	805
4.15 p. m ...	275	165	400	290	.976	....	....	....
4.35 p. m ...	275	170	401	218	.934	....	123	575
Average	274.4	145.36	....	....	.968	70.3	117.8	748.4

State of weather, dull and overcast.
Barometer at noon, 30.12 inches.
Revolutions of blower, 250 per minute.
Kind of fuel, Pocahontas coal, run of mine.
Wood burned in starting fires, 300 pounds.
Coal burned in starting fires, 2,000 pounds.
Coal burned during test, 10,445 pounds.

No. 2.—*Test of Hohenstein water-tube marine boiler, April 26, 1901.*

[Six hours' duration with forced draft, using coal as a fuel.]

Time.	Height of water in gauge glass.	Air pressures in inches of water.			Flue gases.				Water.	
		Fire-room.	Ash pit.	Base of stack.	CO$_2$.	O.	CO.	Dry air per pound carbon.	Fed per hour.	Total weight fed.
	Ins.				*P. ct.*	*P. ct.*	*P. ct.*	*Lbs.*	*Lbs.*	*Lbs.*
10.35 a. m.	2½	......	1.7	−0.80	7.6	6.4	2.3	17.6	......	......
10.45 a. m.	2	......	1.1	− .60	......	......	......	......	......	......
11 a. m	2½	1	.95	− .60	8	5.8	2.2	16.8	......	......
11.15 a. m.	2	1	.95	− .60	......	......	......	......	......	......
11.30 a. m.	1½	1.1	1	− .70	11.2	5.2	1.5	15.6	14,038	14,038
11.45 a. m.	2	1	.95	− .65	......	......	......	......	......	......
12 m	2½	1.1	1	− .65	8.7	5.3	3.6	14.8	......	......
12.15 p. m.	3	1.1	1	− .65	......	......	......	......	......	......
12.30 p. m.	3	1.1	1	− .65	8.8	6	2.4	16.5	15,572	29,610
12.45 p. m.	3½	.9	.85	− .60	......	......	......	......	......	......
1 p. m	2½	1.1	.95	− .65	10.5	5.8	1.7	16.2	......	......
1.15 p. m.	2½	1.2	1.1	− .70	......	......	......	......	......	......
1.30 p. m.	2½	1.1	1	− .70	10.3	6.9	1.6	17.5	15,540	45,150
1.45 p. m.	2½	1.1	1	− .70	......	......	......	......	......	......
2 p. m	2½	1.1	1	− .65	7.6	7.9	2.4	19.2	......	......
2.15 p. m.	2½	1.1	1	− .60	......	......	......	......	......	......
2.30 p. m.	3½	1.1	1	− .65	11.4	6	1	16.6	13.328	58,478
2.45 p. m.	3½	1.1	1	− .65	......	......	......	......	......	......
3 p. m	2	1.1	1	− .65	10.4	7.5	1.6	18	......	......
3.15 p. m.	3	1.1	1	− .65	......	......	......	......	......	......
3.30 p. m.	3	1.1	1	− .65	9.8	6.8	2.2	17	14,278	72,756
3.45 p. m.	2½	1.1	1	− .65	......	......	......	......	......	......
4 p. m	3¾	1.1	1	− .65	9.2	7.4	1.2	19.1	......	......
4.15 p. m.	2½	1.1	1	− .65	......	......	......	......	......	......
4.35 p. m.	3	1.1	1	− .65	9.5	7.5	1.8	18.3	14,074	86,830
Average	......	1.08	1.02	− .654	9.46	6.5	1.96	17.2	14,471	......

Ashes before beginning test, 160 pounds.
Ashes during test, 575 pounds.
Refuse, including sweepings from tubes and baffles, 550 pounds.
Per cent of moisture in coal by weighing and drying sample, 0.5.

Firing very irregular, with average interval of 11 minutes. Average interval between rakings, 9 minutes, varying from 4 minutes to 13 minutes. Average thickness of fire, 12 inches. Average smoke by Ringelmann charts, 2¼. Slicing doors kept closed after 11 o'clock.

No. 3.—*Test of Hohenstein water-tube marine boiler, May 8, 1901.*

[Four hours' duration with forced draft, using coal as a fuel.]

Time.	Steam pressure by gauge.	Temperature of feed water.	Calorimeter.			Temperature.		
			Higher temperature.	Lower temperature.	Quality of steam.	Outside air.	Air in fireroom.	Gases at base of stack.
	Lbs.	° *F.*	° *F.*	° *F.*		° *F.*	° *F.*	° *F.*
12 m	275	....	398	300	0.982	....	108	730
12.15 p. m ..	275	155	396	309	.988	74	112	....
12.30 p. m ..	275	150	398	324	.996	....	119	1,340
12.45 p. m ..	275	140	400	324	.996	....	124	....
1 p. m......	275	142	398	322	.995	76	127	1,240
1.15 p. m ...	275	150	397	314	.991	....	126	....
1.30 p. m ...	275	138	399	314	.991	....	127	1,175
1.45 p. m ...	275	130	399	314	.991	....	128	....
2 p. m......	275	142	399	314	.991	72	129	955
2.15 p. m ...	275	150	399	312	.989	....	127	....
2.30 p. m ...	275	150	400	312	.989	....	125	920
2.45 p. m ...	275	152	398	305	.985	....	115	....
3 p. m......	275	144	299	314	.991	72	121	825
3.15 p. m ...	278	152	400	312	.989	....	123	....
3.30 p. m ...	276	150	401	310	.988	....	120	875
3.45 p. m ...	285	140	400	309	.987	....	119	....
4 p. m......	280	148	400	310	.988	70	120	955
Average	276.1	145.8	....	....	.989	72.8	121.7	1,001.6

State of weather, dull and overcast.
Barometer at noon, 29.86 inches.
Revolutions of blower, 335 per minute.
Kind of fuel, Pocahontas coal, run of mine.
Wood burned in starting fires, 390 pounds.
Coal burned in starting fires, 2,500 pounds.
Coal burned during test, 10,569 pounds.

No. 3.—*Test of Hohenstein water-tube marine boiler, May 8, 1901.*

[Four hours' duration with forced draft, using coal as a fuel.]

Time.	Height of water in gauge glass.	Air pressures in inches of water.			Flue gases.				Water.	
		Fireroom.	Ash pit.	Base of stack.	CO$_2$.	O.	CO.	Dry air per pound carbon.	Fed per hour.	Total weight fed.
	Ins.				*P. ct.*	*P. ct.*	*P. ct.*	*Lbs.*	*Lbs.*	*Lbs.*
12 m					10.1	5.7	1.8	16.2		
12.15 p. m.	+ ½	2.05	2	−0.75						
12.30 p. m.	+ ½	2.05	2	− .85	16	2.1	.0	13.1		
12.45 p. m.	− ½	2.20	2.10	− .90						
1 p. m.	0	2.05	2	− .85	15.2	3	.0	13.8	19,108	19,108
1.15 p. m.	0	2.05	2	− .85						
1.30 p. m.	+ ½	2.05	2	− .85	10	6.4	1.6	17.1		
1.45 p. m.	+ ½	2.05	2	− .85						
2 p. m.	− ½	2.05	2	− .85	13.3	5.2	.7	15.5	19,916	39,024
2.15 p. m.	+ ¾	2.05	2	− .85						
2.30 p. m.	+1½	2.10	2.05	− .85	12.5	5	.9	15.5		
2.45 p. m.	+ ½	2.05	2	− .85						
3 p. m.	0	2	1.95	− .80	12.6	5	1.1	15.3	20,286	59,310
3.15 p. m.	0	2.05	2	− .85						
3.30 p. m.	0	2.10	2	− .85	10	6.9	1.6	17.6		
3.45 p. m.	+2	2	1.95	− .80						
4 p. m.	0	2.05	2	− .80	12.1	4.4	1.3	14.8	20,483	79,794
Average		2.059	2	− .838	12.42	4.85	1	15.4	19,948	

Ashes before beginning of test, 195 pounds.
Ashes during test, 459 pounds.
Refuse, including sweepings from tubes and baffles, 815 pounds.
Per cent of moisture in coal by weighing and drying sample, 0.5.

Fired and raked alternately at intervals averaging 9 minutes for each. Average interval between slicings, 14 minutes, varying from 3 minutes to 31 minutes. Frequent flames in stack, especially during first two hours. Average smoke by Ringelmann charts, 2¼.

No. 4.—*Test of Hohenstein water-tube marine boiler, May 29, 1901.*

[Eight hours' duration with natural draft, using coal as a fuel.]

Time.	Steam pressure by gauge.	Temperature of feed water.	Calorimeter.			Air pressures, in inches of water.				
			Higher temperature.	Lower temperature.	Quality of steam.	Ash pit.	Furnace.	Combustion chamber.	Tube chamber.	Base of stack.
	Lbs.	° *F.*	° *F.*	° *F.*						
9 a. m	272	140	399	300	0.982	0.0	—0.20	—0.20	—0.20	—0.20
9.15 a. m...	272	135	402	310	.987	.0	— .20	— .20	— .20	— .22
9.30 a. m...	275	145	404	313	.988	.0	— .18	— .20	— .20	— .22
9.45 a. m...	275	135	402	315	.990	.0	— .16	— .20	— .20	— .22
10 a. m	275	135	403	316	.990	.0	— .18	— .20	— .20	— .20
10.15 a. m..	275	140	404	316	.990	.0	— .18	— .20	— .20	— .20
10.30 a. m..	275	130	406	316	.989	.0	— .16	— .20	— .20	— .20
10.45 a. m..	275	135	406	316	.989	.0	— .18	— .20	— .20	— .20
11 a. m	272	130	403	316	.990	.0	— .16	— .20	— .20	— .20
11.15 a. m..	275	135	404	316	.990	.0	— .16	— .20	— .20	— .22
11.30 a. m..	273	135	402	316	.990	.0	— .16	— .20	— .20	— .22
11.45 a. m..	275	130	403	316	.990	.0	— .18	— .20	— .20	— .22
12 m	270	135	403	317	.990	.0	— .18	— .20	— .20	— .26
12.15 p. m..	272	135	404	318	.990	.0	— .16	— .20	— .20	— .28
12.30 p. m..	272	138	403	317	.990	.0	— .16	— .20	— .20	— .28
12.45 p. m..	272	135	404	317	.990	.0	— .16	— .20	— .20	— .26
1 p. m	272	140	404	317	.990	.0	— .16	— .20	— .20	— .26
1.15 p. m...	272	135	404	317	.990	— .05	— .16	— .20	— .20	— .26
1.30 p. m...	272	135	403	317	.990	— .05	— .18	— .20	— .20	— .28
1.45 p. m...	274	135	403	317	.990	— .05	— .18	— .20	— .20	— .28
2 p. m	270	135	402	317	.991	— .05	— .20	— .22	— .22	— .28
2.15 p. m...	270	140	403	317	.990	.0	— .18	— .20	— .20	— .26
2.30 p. m...	270	145	404	317	.990	.0	— .18	— .20	— .20	— .28
2.45 p. m...	272	142	404	317	.990	.0	— .18	— .20	— .20	— .26
3 p. m	272	140	404	316	.990	.0	— .18	— .20	— .20	— .28
3.15 p.m ...	275	140	406	318	.990	.0	— .16	— .20	— .20	— .26
3.30 p. m...	273	150	404	317	.990	.0	— .16	— .20	— .20	— .24
3.45 p. m...	272	150	404	321	.993	.0	— .18	— .20	— .20	— .24
4 p. m	274	130	404	324	.995	.0	— .18	— .20	— .20	— .26
4.15 p. m...	272	135	403	324	.995	.0	— .20	— .22	— .22	— .28
4.30 p. m...	272	135	403	326	.996	— .02	— .20	— .22	— .22	— .30
4.45 p. m...	274	135	404	330	.998	— .02	— .22	— .25	— .25	— .30
5 p. m	274	130	403	324	.995	— .02	— .20	— .25	— .25	— .28
Average ...	272.8	137	....	....	.990	— .0008	— .177	— .20	— .20	— .24

State of weather, squally.
Barometer at noon, 29.70 inches.
Kind of fuel, Pocahontas coal, run of mine.
Wood burned in starting fires, 340 pounds.
Coal burned in starting fires, 2,000 pounds.
Coal burned during test, 8,633 pounds.
Ashes before beginning of test, 175 pounds.
Ashes during test, 226 pounds.

No. 4.—*Test of Hohenstein water-tube marine boiler, May 29, 1901.*

[Eight hours' duration with natural draft, using coal as a fuel.]

Time.	Height of water in gauge glass.	Temperature.			Flue gases.				Water.	
		Outside air.	Air in fireroom.	Gases at base of stack.	CO_2.	O.	CO.	Dry air per pound carbon.	Fed per hour.	Total weight fed.
	Ins.	° *F.*	° *F.*	° *F.*	*P. ct.*	*P. ct.*	*P. ct.*	*Lbs.*	*Lbs.*	*Lbs.*
9 a. m	0	60	93	......	......	......	......	......	......	......
9.15 a. m..	0	......	95	......	......	......	......	......	......	......
9.30 a. m..	0	......	102	610	13	4	1.5	14.1	......	......
9.45 a. m..	0	......	104	......	......	......	......	......	......	......
10 a. m ...	0	60	104	605	11.2	5.1	1.7	15.4	10,570	10,570
10.15 a. m.	0	......	107	......	......	......	......	......	......	......
10.30 a. m.	0	......	108	610	12.3	4.7	1.6	14.8	......	......
10.45 a. m.	+½	......	111	......	......	......	......	......	......	......
11 a. m ...	0	60	111	610	11.5	6	1.4	16.3	10,252	20,822
11.15 a. m.	0	......	109	......	......	......	......	......	......	......
11.30 a. m.	0	......	111	660	11.2	5.1	1.4	15.6	......	......
11.45 a. m.	0	......	100	......	......	......	......	......	......	......
12 m	0	64	114	660	9.5	5.2	2.8	14.9	10,320	31,142
12.15 p. m.	+½	......	115	......	......	......	......	......	......	......
12.30 p. m.	+½	......	113	665	11.4	3.7	2.6	13.5	......	......
12.45 p. m.	0	......	112	......	......	......	......	......	......	......
1 p. m	0	66	113	655	10.1	7.4	1.2	18.5	9,994	41,136
1.15 p. m..	0	......	112	......	......	......	......	......	......	......
1.30 p. m..	0	......	112	670	10.9	4.5	2.8	14.1	......	......
1.45 p. m..	0	......	111	......	......	......	......	......	......	......
2 p. m	0	66	113	735	9.4	5.3	2.5	15.5	9,653	50,789
2.15 p. m..	0	......	117	......	......	......	......	......	......	......
2.30 p. m..	+½	......	122	665	10.4	4	3.1	13.7	......	......
2.45 p. m..	0	......	124	......	......	......	......	......	......	......
3 p. m	0	70	125	650	11.6	4.9	2	14.9	9,122	59,911
3.15 p. m..	0	......	126	......	......	......	......	......	......	......
3.30 p. m..	0	......	127	665	10.7	3.7	3.3	13.2	......	......
3.45 p. m..	0	......	129	......	......	......	......	......	......	......
4 p. m	+½	66	126	845	11.4	4.4	2	14.5	8,846	68,757
4.15 p. m..	0	......	125	......	......	......	......	......	......	......
4.30 p. m..	0	......	124	850	11.7	3.5	3	13.1	......	......
4.45 p. m..	0	......	124	......	......	......	......	......	......	......
5 p. m	0	68	125	640	......	......	......	......	9,192	77,949
Average ..	......	64.4	114	675	11.08	4.75	2.19	14.8	9,744	......

Refuse, including sweepings from tubes and baffles, 549 pounds.

Per cent of moisture in coal by chemical analysis, 0.79.

Average interval between firings, six and a half minutes. Average interval between rakings, eight minutes. Average thickness of fire, 6 inches. The draft was checked by means of a damper in the smokepipe, so as to keep the rate of combustion at about 1,100 pounds of coal per hour. Average smoke by Ringelmann charts, 2.2. At 1.40 o'clock two bricks came down from combustion-chamber baffle.

No. 5.—*Test of Hohenstein water-tube marine boiler, June 5, 1901.*

[Six hours' duration with forced draft, using coal as a fuel.]

Time.	Steam pressure by gauge.	Temperature of feed water.	Calorimeter.			Air pressures in inches of water.				
			Higher temperature.	Lower temperature.	Quality of steam.	Fireroom.	Ash pit.	Furnace.	Combustion chamber.	Base of stack.
	Lbs.	° *F.*	° *F.*	° *F.*						
9.30 a. m ..	275	130	400	304	0.984	1	0.95	0.80	0.60	−0.4
9.45 a. m ..	270	125	401	304	.984	1	1	.85	.60	− .4
10 a. m	275	125	402	307	.985	1.05	1	.85	.60	− .45
10.15 a. m .	275	130	402	309	.987	1.10	1.05	.85	.60	− .45
10.30 a. m .	275	130	402	308	.986	1.05	1	.85	.60	− .4
10.45 a. m .	275	136	402	309	.987	1	.95	.85	.60	− .4
11 a. m	275	132	400	309	.986	1	.95	.80	.60	− .4
11.15 a. m .	272	128	401	310	.987	1	.95	.70	.55	− .4
11.30 a. m .	273	130	402	310	.988	1	.95	.75	.60	− .4
11.45 a. m .	273	120	402	310	.988	1	.95	.75	.60	− .4
12 m	273	130	402	312	.989	1.10	1.05	.70	.60	− .4
12.15 p. m .	275	130	402	311	.988	1.10	1.05	.75	.60	− .4
12.30 p. m .	275	130	401	312	.988	1.10	1.05	.85	.65	− .4
12.45 p. m .	275	128	402	313	.989	1.10	1.05	.80	.65	− .4
1 p. m	275	130	401	314	.990	1.10	1.05	.85	.65	− .4
1.15 p. m ..	275	132	402	314	.990	1.10	1.05	.85	.65	− .4
1.30 p. m ..	275	128	402	313	.989	1.10	1.05	.80	.65	− .4
1.45 p. m ..	275	134	402	316	.981	1.10	1.05	.80	.65	− .4
2 p. m	275	130	401	317	.992	1.10	1.05	.85	.70	− .4
2.15 p. m ..	275	130	401	317	.992	1.10	1.05	.80	.65	− .4
2.30 p. m ..	273	132	401	311	.987	1.10	1.05	.75	.65	− .4
2.45 p. m ..	273	126	402	314	.990	1.10	1.05	.80	.65	− .4
3 p. m	275	128	403	316	.990	1.10	1.05	.80	.65	− .4
3.15 p. m ..	272	126	404	317	.990	1.10	1.05	.80	.65	− .4
3.30 p. m ..	272	132	401	318	.992	1	.95	.75	.60	− .4
Average ...	274	126.6	......	......	.988	1.064	1.016	.80	.624	− .404

State of weather, bright and sunshiny.
Barometer at noon, 30.08 inches.
Revolutions of blower, 243 per minute.
Kind of fuel, Pocahontas coal, run of mine.
Wood burned in starting fires, 360 pounds.
Coal burned in starting fires, 2,200 pounds.
Coal burned during test, 10,695 pounds.

No. 5.—*Test of Hohenstein water-tube marine boiler, June 5, 1901.*

[Six hours' duration with forced draft, using coal as a fuel.]

Time.	Height of water in gauge glass.	Temperature.			Flue gases.				Water.	
		Outside air.	Air in fireroom.	Gases at base of stack.	CO$_2$.	O.	CO.	Dry air per pound carbon.	Fed per hour.	Total weight fed.
	Ins.	° *F.*	° *F.*	° *F.*	*P. ct.*	*P. ct.*	*P. ct.*	*Lbs.*	*Lbs.*	*Lbs.*
9.30 a. m	0	80	118	......	......	......	......	......	......	......
9.45 a. m	+1	......	125	......	......	......	......	......	......	......
10 a. m	0	......	130	730	12.2	4.4	1.6	14.5	......	......
10.15 a. m	0	......	133	......	......	......	......	......	......	......
10.30 a. m	0	82	135	660	10	5.7	2	16.1	15,200	15,200
10.45 a. m	0	......	137	......	......	......	......	......	......	......
11 a. m	+1	......	138	690	11.1	4.3	2.1	14.4	......	......
11.15 a. m	0	......	139	......	......	......	......	......	......	......
11.30 a. m	0	84	139	675	9.7	5.2	2.3	15.4	15,041	30,241
11.45 a. m	0	......	139	......	......	......	......	......	......	......
12 m	0	......	143	675	11	4.3	2	14.5	......	......
12.15 p. m	+½	......	141	......	......	......	......	......	......	......
12.30 p. m	+½	85	140	740	12.2	4.8	1.4	15	16,505	46,746
12.45 p. m	0	......	142	......	......	......	......	......	......	......
1 p. m	+½	......	141	700	10.7	4.8	2.2	14.9	......	......
1.15 p. m	0	......	141	......	......	......	......	......	......	......
1.30 p. m	+1	86	143	700	10	6.6	1.8	17.1	14,914	61,660
1.45 p. m	+1	......	142	......	......	......	......	......	......	......
2 p. m	+½	......	144	670	9.8	4.9	2.7	14.8	......	......
2.15 p. m	+½	......	147	......	......	......	......	......	......	......
2.30 p. m	0	86	146	670	9.4	5.7	2.3	16	15,270	76,930
2.45 p. m	0	......	145	......	......	......	......	......	......	......
3 p. m	0	......	146	745	11.2	4.3	2.1	14.4	......	......
3.15 p. m	0	......	146	......	......	......	......	......	......	......
3.45 p. m	0	86	148	528	6.9	5.4	3.9	15.2	15,534	92,464
Average	......	84.1	139.5	681	10.35	5.03	2.2	15.2	15,411	......

Ashes before beginning test, 200 pounds.
Ashes during test, 1,038 pounds.
Refuse, including sweepings from tubes and baffles, 539 pounds.
Per cent of moisture in coal, by chemical analysis, 0.79.
Fired and raked alternately at intervals averaging 8 minutes for each. Average smoke by Ringelmann charts, 2.2.

No. 6.—*Test of Hohenstein water-tube marine boiler, June 8, 1901.*

[Three and one-half hours' duration with forced draft, using coal as a fuel.]

Time.	Steam pressure by gauge.	Temperature of feed water.	Calorimeter.			Air pressures in inches of water.				
			Higher temperature.	Lower temperature.	Quality of steam.	Fireroom.	Ash pit.	Furnace.	Combustion chamber.	Base of stack.
	Lbs.	° *F.*	° *F.*	° *F.*						
9.30 a. m...	275	112	398	296	0.980	2	1.95	1.50	1.35	—0.30
9.45 a. m...	273	118	398	310	.988	2	1.90	1.50	1.35	— .30
10 a. m	270	118	398	311	.989	2	1.95	1.55	1.40	— .30
10.15 a. m..	272	112	399	309	.988	2	1.90	1.55	1.40	— .25
10.30 a. m..	272	110	399	310	.988	2	1.95	1.60	1.45	— .20
10.45 a. m..	270	112	399	309	.988	2	1.95	1.60	1.45	— .20
11 a. m	270	110	399	306	.985	2.1	2	1.65	1.45	— .25
11.15 a. m..	272	108	400	306	.986	2.1	2	1.70	1.50	— .15
11.30 a. m..	270	110	399	321	.995	2.2.	2.15	1.70	1.50	— .10
11.45 a. m..	272	112	400	324	.996	2	2.05	1.60	1.40	— .15
12 m	275	120	400	319	.993	1.95	1.90	1.45	1.30	— .20
12.15 p. m..	273	130	400	317	.992	2	1.95	1.50	1.40	— .30
12.30 p. m..	272	130	400	324	.996	2	1.95	1.45	1.40	— .30
12.45 p. m..	272	130	401	329	.999	2	1.95	1.50	1.45	— .30
1 p. m	......	......	399	328	.998	......	......	......	......	......
Average ...	272	116.5	.....	......	.990	2.025	1.968	1.56	1.41	— .235

State of weather, bright and sunshiny.
Barometer at noon, 29.95 inches.
Revolutions of blower, 375 per minute.
Kind of fuel, Pocahontas coal, run of mine.
Coal burned during test, 8,736—275=8,461 pounds.
Ashes during test, 591 pounds.

No. 6.—*Test of Hohenstein water-tube marine boiler, June 8, 1901.*

[Three and one-half hours' duration with forced draft, using coal as a fuel.]

Time.	Height of water in gauge glass.	Temperature.			Flue gases.				Water.	
		Outside air.	Air in fireroom.	Gases at base of stack.	CO_2.	O.	CO.	Dry air per pound carbon.	Fed per hour.	Total weight fed.
	Ins.	° *F.*	° *F.*	° *F.*	*P. ct.*	*P. ct.*	*P. ct.*	*Lbs.*	*Lbs.*	*Lbs.*
9.30 a. m.	0	70	106	......	......	......	......	......	......	......
9.45 a. m.	0	......	116	......	......	......	......	......	......	......
10 a. m.	0	......	120	840	13	......	2.2	......	......	......
10.15 a. m.	0	......	120	......	......	......	......	......	......	......
10.30 a. m.	0	76	124	930	10.5	3.9	1.9	14.3	17,641	17,641
10.45 a. m.	0	......	124	......	......	......	......	......	......	......
11 a. m.	0	......	124	800	11.8	4.9	1.3	15.3	......	......
11.15 a. m.	0	......	128	......	......	......	......	......	......	......
11.30 a. m.	0	76	131	1,450	17.8	.7	.1	12	17,521	35,162
11.45 a. m.	0	......	132	......	......	......	......	......	......	......
12 m.	+ ½	......	133	1,240	16.7	1.7	.2	12.6	......	......
12.15 p. m.	0	......	134	......	......	......	......	......	......	......
12.30 p. m.	0	77	137	1,060	16.6	2.4	.1	13.2	16,648	51,810
12.45 p. m.	0	......	140	......	......	......	......	......	......	......
1 p. m.	0	......	141	1,560	10	8.8	.7	20.6	8,729	60,539
Average	......	74.75	127.3	1,125.7	13.77	3.73	.928	14.66	17,297	......

Refuse, including sweepings from tubes and baffles, 626 pounds.

Per cent of moisture in coal by chemical analysis, 0.79.

Fired and raked alternately at intervals averaging 6 minutes for each. Average smoke by Ringelmann charts, 3.4. Almost continual flaming in stack. Base of stack occasionally red hot. Test stopped prematurely at 1 o'clock on account of roof taking fire. The fires were about 2 inches thicker at end of trial than at beginning, corresponding to a difference of about 275 pounds of coal.

No. 7.—*Test of Hohenstein water-tube marine boiler, October 21, 1901.*

[Eight hours' duration with natural draft, using coal as a fuel.]

Time.	Steam pressure by gauge.	Temperature of feed water.	Calorimeter.			Air pressures in inches of water.				
			Higher temperature.	Lower temperature.	Quality of steam.	Ash pit.	Furnace.	Combustion chamber.	Tube chamber.	Base of stack.
	Lbs.	° *F.*	° *F.*	° *F.*						
8.30 a. m...	......	......	404	306	0.984	......	......	......	......	......
8.45 a. m...	275	126	404	307	.985	—0.05	—0.10	—0.07	—0.15	—0.50
9 a. m	275	124	404	307	.985	— .05	— .10	— .06	— .20	— .50
9.15 a. m...	275	124	404	309	.986	— .05	— .10	— .06	— .20	— .50
9.30 a. m...	275	128	404	309	.986	— .05	— .10	— .06	— .20	— .50
9.45 a. m...	275	124	404	309	.986	— .05	— .10	— .06	— .20	— .50
10 a. m	275	126	404	309	.986	— .05	— .10	— .06	— .20	— .50
10.15 a. m..	275	128	404	309	.986	— .05	— .12	— .08	— .22	— .50
10.30 a. m..	275	130	404	310	.986	— .05	— .14	— .08	— .22	— .50
10.45 a. m..	275	128	404	310	.986	— .05	— .16	— .10	— .24	— .50
11 a. m	275	128	404	310	.986	— .05	— .16	— .10	— .24	— .50
11.15 a. m..	275	126	404	310	.986	— .05	— .16	— .10	— .24	— .50
11.30 a. m..	275	126	404	310	.986	— .05	— .16	— .08	— .22	— .50
11.45 a. m..	275	134	404	310	.986	— .05	— .16	— .12	— .24	— .50
12 m	275	134	404	310	.986	— .05	— .18	— .12	— .22	— .50
12.15 p. m .	275	128	403	310	.987	— .05	— .18	— .12	— .22	— .50
12.30 p. m .	275	130	404	310	.986	— .05	— .18	— .14	— .22	— .50
12.45 p. m .	275	130	404	310	.986	— .05	— .18	— .14	— .22	— .50
1 p. m.....	275	130	404	312	.987	— .05	— .18	— .14	— .22	— .50
1.15 p. m ..	275	132	404	311	.987	— .05	— .20	— .14	— .22	— .50
1.30 p. m ..	275	134	404	312	.987	— .05	— .20	— .14	— .22	— .50
1.45 p. m ..	275	132	404	311	.987	— .05	— .18	— .14	— .22	— .50
2 p. m.....	275	130	404	310	.986	— .05	— .20	— .14	— .22	— .50
2.15 p. m ..	275	134	402	311	.988	— .05	— .18	— .14	— .22	— .50
2.30 p. m ..	275	134	404	311	.987	— .05	— .18	— .15	— .22	— .50
2.45 p. m ..	275	136	404	310	.986	— .05	— .18	— .15	— .22	— .50
3 p. m.....	275	138	404	310	.986	— .05	— .16	— .15	— .22	— .50
3.15 p. m ..	275	140	404	310	.986	— .05	— .16	— .15	— .22	— .50
3.30 p. m ..	275	140	404	310	.986	— .05	— .16	— .15	— .22	— .50
3.45 p. m ..	275	140	404	311	.987	— .05	— .16	— .15	— .22	— .50
4 p. m.....	275	142	404	311	.987	— .05	— .16	— .15	— .22	— .50
4.15 p. m ..	275	140	404	312	.988	— .05	— .14	— .14	— .20	— .50
4.30 p. m ..	275	142	404	312	.988	— .05	— .14	— .14	— .20	— .50
Average ...	275	131.8	.....	.....	.986	— .05	— .155	— .116	— .216	— .50

State of weather, clear.
Barometer at noon, 30.34 inches.
Kind of fuel, New River coal, run of mine.
Wood burned in starting fires, 360 pounds.
Coal burned in starting fires, 2,000 pounds.
Ashes before beginning test, 198 pounds.
Ashes during test, 485 pounds.

No. 7.—*Test of Hohenstein water-tube marine boiler, October 21, 1901.*

[Eight hours' duration with natural draft, using coal as a fuel.]

Time.	Height of water in gauge glass.	Temperature.			Flue gases.				Coal fired per hour.	Water fed per hour.
		Outside air.	Air in fireroom.	Gases at base of stack.	CO_2.	O.	CO.	Dry air per pound carbon.		
	Ins.	° *F.*	° *F.*	° *F.*	*P. ct.*	*P. ct.*	*P. ct.*	*Lbs.*	*Lbs.*	*Lbs.*
8.30 a. m.	2½	......	110	......	......	......	......	......	......	......
8.45 a. m.	2½	60	117	540	9.7	6.2	1.1	17.5	......	......
9 a. m.	2½	......	117	......	......	......	......	......	......	......
9.15 a. m.	2	......	121	555	10	5.8	1.1	17	......	......
9.30 a. m.	2	......	126	......	......	......	......	......	1,300	9,534
9.45 a. m.	2	66	130	535	10.1	5.6	2	15.9	......	......
10 a. m.	2	......	137	......	......	......	......	......	......	......
10.15 a. m.	2½	......	137	570	9.5	5.7	2.1	16.2	......	......
10.30 a. m.	2	......	138	......	......	......	......	......	1,175	9,554
10.45 a. m.	2¼	68	140	575	10	6.5	1.1	17.7	......	......
11 a. m.	2	......	143	......	......	......	......	......	......	......
11.15 a. m.	2	......	141	560	10	5.7	1.8	16.2	......	......
11.30 a. m.	2½	......	144	......	......	......	......	......	1,125	9,693
11.45 a. m.	2	72	148	581	10.2	6.2	1.6	16.8	......	......
12 m.	2	......	143	......	......	......	......	......	......	......
12.15 p. m.	2½	......	148	560	9.2	7.4	1.2	19.1	......	......
12.30 p. m.	2½	......	148	......	......	......	......	......	1,100	9,058
12.45 p. m.	2½	74	147	584	9.2	6.8	1.7	17.8	......	......
1 p. m.	2¾	......	144	......	......	......	......	......	......	......
1.15 p. m.	2½	......	148	550	9.2	6.8	1.8	17.7	......	......
1.30 p. m.	2¾	......	144	......	......	......	......	......	1,100	8,660
1.45 p. m.	2¾	76	150	560	9.1	7.7	1	19.7	......	......
2 p. m.	2¾	......	143	......	......	......	......	......	......	......
2.15 p. m.	2½	......	150	560	8.7	6.8	2.3	17.5	......	......
2.30 p. m.	2½	......	158	......	......	......	......	......	1,000	8,381
2.45 p. m.	2¾	76	162	570	8.5	6.1	1.6	17.6	......	......
3 p. m.	2¾	......	164	......	......	......	......	......	......	......
3.15 p. m.	2¾	......	160	565	8	6.4	1.8	18	......	......
3.30 p. m.	2½	......	159	......	......	......	......	......	650	7,217
3.45 p. m.	2½	78	162	570	8.8	6.7	1.2	18.5	......	......
4 p. m.	2½	......	160	......	......	......	......	......	......	......
4.15 p. m.	3	......	156	565	8	7.3	.9	20.4	......	......
4.30 p. m.	3	......	155	......	......	......	......	......	605	6,475
Average	......	71¼	144	562½	9.26	6.48	1.52	17.7	1,007	8,558

Refuse, including sweepings from tubes and baffles, 561 pounds.

Per cent of moisture in coal by weighing and drying samples, 8.14.

Average interval between firings, 6 minutes. Raked and sliced alternately between firings. Thickness of fire during first four hours, 6 inches; for next two hours, 9 inches; then allowed to burn down to original thickness. Average smoke by Ringelmann charts, 2.

Total weight of coal fired, 8,055 pounds.

Total weight of water fed, 68,572 pounds.

No. 8.—*Test of Hohenstein water-tube marine boiler, October 23, 1901.*

[Six hours' duration with forced draft, using coal as a fuel.]

Time.	Steam pressure by gauge.	Temperature of feed water.	Calorimeter.			Air pressure in inches of water.					
			Higher temperature.	Lower temperature.	Quality of steam.	Fireroom.	Ash pit.	Furnace.	Combustion chamber.	Tube chamber.	Base of stack.
	Lbs.	° *F.*	° *F.*	° *F.*							
9 a. m	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
9.15 a. m ..	275	128	403	292	0.976	1	0.95	0.80	0.70	0.45	−0.50
9.30 a. m ..	275	130	402	292	.977	1.05	.95	.78	.70	.50	− .47
9.45 a. m ..	275	120	402	295	.979	1.05	1	.70	.65	.45	− .45
10 a. m	275	120	402	292	.977	1.05	1	.75	.70	.48	− .42
10.15 a. m .	275	118	402	292	.977	1.05	1	.75	.70	.45	− .45
10.30 a. m .	275	119	402	293	.977	1.05	1	.75	.68	.45	− .43
10.45 a. m .	275	124	402	292	.977	1.05	1	.80	.70	.50	− .45
11 a. m	275	120	402	293	.977	1.08	1	.75	.70	.50	− .45
11.15 a. m .	275	129	402	296	.979	1.08	1	.80	.70	.50	− .43
11.30 a. m .	275	122	402	292	.977	1.08	1	.80	.70	.50	− .45
11.45 a. m .	275	126	402	290	.976	1.05	1	.80	.70	.50	− .45
12 m	275	128	402	290	.976	1.08	1	.82	.75	.55	− .42
12.15 p. m .	275	126	402	292	.977	1.10	1	.85	.72	.55	− .45
12.30 p. m .	275	122	402	292	.977	1.10	1	.85	.72	.55	− .48
12.45 p. m .	275	128	402	291	.976	1.10	1	.85	.76	.58	− .45
1 p. m	275	126	401	289	.976	1.10	1	.85	.75	.55	− .50
1.15 p. m ..	275	124	402	290	.976	1.08	1	.85	.75	.55	− .50
1.30 p. m ..	275	122	402	289	.975	1.08	1	.85	.75	.55	− .50
1.45 p. m ..	275	126	402	289	.975	1.08	1	.85	.75	.55	− .48
2 p. m	275	132	402	291	.976	1.05	1	.85	.75	.55	− .48
2.15 p. m ..	275	136	402	288	.975	1.08	1	.85	.75	.55	− .48
2.30 p. m ..	275	132	402	288	.975	1.08	1	.85	.75	.55	− .48
2.45 p. m ..	275	130	402	288	.975	1.10	1.05	.85	.75	.50	− .48
3 p. m	275	138	402	288	.975	1.10	1.05	.85	.75	.50	− .48
Average ...	275	126.1	.....	.....	.976	1.07	1	.813	.722	.515	− .464

State of weather, cloudy.
Barometer at noon, 29.95 inches.
Kind of fuel, New River coal, run of mine.
Wood burned in starting fires, 250 pounds.
Coal burned in starting fires, 1,910 pounds.
Ashes before beginning test, 161 pounds.
Ashes during test, 365 pounds.

No. 8.—*Test of Hohenstein water-tube marine boiler, October 23, 1901.*

[Six hours' duration with forced draft, using coal as a fuel.]

Time.	Height of water in gauge glass.	Temperature.			Flue gases.				Coal fired per hour.	Water fed per hour.
		Outside air.	Air in fireroom.	Gases at base of stack.	CO_2.	O.	CO.	Dry air per pound carbon.		
	Ins.	*° F.*	*° F.*	*° F.*	*Per ct.*	*Per ct.*	*Per ct.*	*Lbs.*	*Lbs.*	*Lbs.*
9 a. m	2½		106							
9.15 a. m	2½	70	111	630	8.6	7.3	1.5	19		
9.30 a. m	2½		114							
9.45 a. m	2¾		116	637	8.9	7	2.1	17.8		
10 a. m	2½		118						2,000	13,996
10.15 a. m	2½	72	118	670	9	6.5	1.5	17.8		
10.30 a. m	2½		123							
10.45 a. m	2½		120	630	7.7	7	2.9	17.6		
11 a. m	2½		123						1,800	14,508
11.15 a. m	3	76	128	680	9	6.3	1.9	17.2		
11.30 a. m	2¾		124							
11.45 a. m	2½		124	678	8.6	7.2	1.1	19.5		
12 m	2¾		128						1,800	14,344
12.15 p. m	3	76	125	667	9.5	6.7	1.6	17.7		
12.30 p. m	3		127							
12.45 p. m	3		128	660	9.5	6.6	1.3	17.9		
1 p. m	2½		130						1,600	14,194
1.15 p. m	2¾	76	129	660	10	6.6	1.1	17.8		
1.30 p. m	3		128							
1.45 p. m	4		128	680	9	7.2	1.6	18.5		
2 p. m	3		124						1,400	13,459
2.15 p. m	2½	76	127	635	9.1	8.3	.6	21		
2.30 p. m	2½		131							
2.45 p. m	2½		131	620	7.5	6.6	1.9	18.5		
3 p. m	2½		126						1,098	10,246
Average		74.34	123.5	654	8.87	6.94	1.59	18.4	1,616	13,458

Refuse, including sweepings from tubes and baffles, 528 pounds.

Per cent of moisture in coal by weighing and drying sample, 3.14.

Average interval between firings, six minutes. Raked and sliced alternately between firings. Occasional flames in stack. Average smoke by Ringelmann charts, 2.

Total weight of coal fired, 9,698 pounds.

Total weight of water fed, 80,747 pounds.

No. 5.—*Test of Hohenstein water-tube marine boiler, June 5, 1901.*

[Six hours' duration with forced draft, using coal as a fuel.]

Time.	Steam pressure by gauge.	Temperature of feed water.	Calorimeter.			Air pressures in inches of water.				
			Higher temperature.	Lower temperature.	Quality of steam.	Fireroom.	Ash pit.	Furnace.	Combustion chamber.	Base of stack.
	Lbs.	° *F.*	° *F.*	° *F.*						
9.30 a. m.	275	130	400	304	0.984	1	0.95	0.80	0.60	—0.4
9.45 a. m.	270	125	401	304	.984	1	1	.85	.60	— .4
10 a. m.	275	125	402	307	.985	1.05	1	.85	.60	— .45
10.15 a. m.	275	130	402	309	.987	1.10	1.05	.85	.60	— .45
10.30 a. m.	275	130	402	308	.986	1.05	1	.85	.60	— .4
10.45 a. m.	275	136	402	309	.987	1	.95	.85	.60	— .4
11 a. m.	275	132	400	309	.986	1	.95	.80	.60	— .4
11.15 a. m.	272	128	401	310	.987	1	.95	.70	.55	— .4
11.30 a. m.	273	130	402	310	.988	1	.95	.75	.60	— .4
11.45 a. m.	273	120	402	310	.988	1	.95	.75	.60	— .4
12 m.	273	130	402	312	.989	1.10	1.05	.70	.60	— .4
12.15 p. m.	275	130	402	311	.988	1.10	1.05	.75	.60	— .4
12.30 p. m.	275	130	401	312	.988	1.10	1.05	.85	.65	— .4
12.45 p. m.	275	128	402	313	.989	1.10	1.05	.80	.65	— .4
1 p. m.	275	130	401	314	.990	1.10	1.05	.85	.65	— .4
1.15 p. m.	275	132	402	314	.990	1.10	1.05	.85	.65	— .4
1.30 p. m.	275	128	402	313	.989	1.10	1.05	.80	.65	— .4
1.45 p. m.	275	134	402	316	.981	1.10	1.05	.80	.65	— .4
2 p. m.	275	130	401	317	.992	1.10	1.05	.85	.70	— .4
2.15 p. m.	275	130	401	317	.992	1.10	1.05	.80	.65	— .4
2.30 p. m.	273	132	401	311	.987	1.10	1.05	.75	.65	— .4
2.45 p. m.	273	126	402	314	.990	1.10	1.05	.80	.65	— .4
3 p. m.	275	128	403	316	.990	1.10	1.05	.80	.65	— .4
3.15 p. m.	272	126	404	317	.990	1.10	1.05	.80	.65	— .4
3.30 p. m.	272	132	401	318	.992	1	.95	.75	.60	— .4
Average	274	126.6	.....	......	.988	1.064	1.016	.80	.624	— .404

State of weather, bright and sunshiny.
Barometer at noon, 30.08 inches.
Revolutions of blower, 243 per minute.
Kind of fuel, Pocahontas coal, run of mine.
Wood burned in starting fires, 360 pounds.
Coal burned in starting fires, 2,200 pounds.
Coal burned during test, 10,695 pounds.

No. 5.—*Test of Hohenstein water-tube marine boiler, June 5, 1901.*

[Six hours' duration with forced draft, using coal as a fuel.]

Time.	Height of water in gauge glass.	Temperature.			Flue gases.				Water.	
		Outside air.	Air in fireroom.	Gases at base of stack.	CO_2.	O.	CO.	Dry air per pound carbon.	Fed per hour.	Total weight fed.
	Ins.	° *F.*	° *F.*	° *F.*	*P. ct.*	*P. ct.*	*P. ct.*	*Lbs.*	*Lbs.*	*Lbs.*
9.30 a. m.	0	80	118	......	......	......	......	......	......	......
9.45 a. m.	−1	......	125	......	......	......	......	......	......	......
10 a. m.	0	......	130	730	12.2	4.4	1.6	14.5	......	......
10.15 a. m.	0	......	133	......	......	......	......	......	......	......
10.30 a. m.	0	82	135	660	10	5.7	2	16.1	15,200	15,200
10.45 a. m.	0	......	137	......	......	......	......	......	......	......
11 a. m.	+1	......	138	690	11.1	4.3	2.1	14.4	......	......
11.15 a. m.	0	......	139	......	......	......	......	......	......	......
11.30 a. m.	0	84	139	675	9.7	5.2	2.3	15.4	15,041	30,241
11.45 a. m.	0	......	139	......	......	......	......	......	......	......
12 m.	0	......	143	675	11	4.3	2	14.5	......	......
12.15 p. m.	+ ½	......	141	......	......	......	......	......	......	......
12.30 p. m.	+ ½	85	140	740	12.2	4.8	1.4	15	16,505	46,746
12.45 p. m.	0	......	142	......	......	......	......	......	......	......
1 p. m.	+ ½	......	141	700	10.7	4.8	2.2	14.9	......	......
1.15 p. m.	0	......	141	......	......	......	......	......	......	......
1.30 p. m.	−1	86	143	700	10	6.6	1.8	17.1	14,914	61,660
1.45 p. m.	+1	......	142	......	......	......	......	......	......	......
2 p. m.	+ ½	......	144	670	9.8	4.9	2.7	14.8	......	......
2.15 p. m.	+ ½	......	147	......	......	......	......	......	......	......
2.30 p. m.	0	86	146	670	9.4	5.7	2.3	16	15,270	76,930
2.45 p. m.	0	......	145	......	......	......	......	......	......	......
3 p. m.	0	......	146	745	11.2	4.3	2.1	14.4	......	......
3.15 p. m.	0	......	146	......	......	......	......	......	......	......
3.45 p. m.	0	86	148	528	6.9	5.4	3.9	15.2	15,534	92,464
Average	......	84.1	139.5	681	10.35	5.03	2.2	15.2	15,411	......

Ashes before beginning test, 200 pounds.
Ashes during test, 1,038 pounds.
Refuse, including sweepings from tubes and baffles, 539 pounds.
Per cent of moisture in coal, by chemical analysis, 0.79.
Fired and raked alternately at intervals averaging 8 minutes for each. Average smoke by Ringelmann charts, 2.2.

No. 3.—*Test of Hohenstein water-tube marine boiler, May 8, 1901.*

[Four hours' duration with forced draft, using coal as a fuel.]

Time.	Steam pressure by gauge.	Temperature of feed water.	Calorimeter.			Temperature.		
			Higher temperature.	Lower temperature.	Quality of steam.	Outside air.	Air in fireroom.	Gases at base of stack.
	Lbs.	° *F.*	° *F.*	° *F.*		° *F.*	° *F.*	° *F.*
12 m	275	....	398	300	0.982	....	108	730
12.15 p. m ..	275	155	396	309	.988	74	112	....
12.30 p. m ..	275	150	398	324	.996	....	119	1,340
12.45 p. m ..	275	140	400	324	.996	....	124	....
1 p. m......	275	142	398	322	.995	76	127	1,240
1.15 p. m ...	275	150	397	314	.991	....	126	....
1.30 p. m ...	275	138	399	314	.991	....	127	1,175
1.45 p. m ...	275	130	399	314	.991	....	128	....
2 p. m......	275	142	399	314	.991	72	129	955
2.15 p. m ...	275	150	399	312	.989	....	127	....
2.30 p. m ...	275	150	400	312	.989	....	125	920
2.45 p. m ...	275	152	398	305	.985	....	115	....
3 p. m......	275	144	299	314	.991	72	121	825
3.15 p. m ...	278	152	400	312	.989	....	123	....
3.30 p. m ...	276	150	401	310	.988	....	120	875
3.45 p. m ...	285	140	400	309	.987	....	119	....
4 p. m......	280	148	400	310	.988	70	120	955
Average	276.1	145.8	....	....	.989	72.8	121.7	1,001.6

State of weather, dull and overcast.
Barometer at noon, 29.86 inches.
Revolutions of blower, 335 per minute.
Kind of fuel, Pocahontas coal, run of mine.
Wood burned in starting fires, 390 pounds.
Coal burned in starting fires, 2,500 pounds.
Coal burned during test, 10,569 pounds.

No. 3.—*Test of Hohenstein water-tube marine boiler, May 8, 1901.*

[Four hours' duration with forced draft, using coal as a fuel.]

Time.	Height of water in gauge glass.	Air pressures in inches of water.			Flue gases.			Dry air per pound carbon.	Water.	
		Fireroom.	Ash pit.	Base of stack.	CO₂.	O.	CO.		Fed per hour.	Total weight fed.
	Ins.				*P. ct.*	*P. ct.*	*P. ct.*	*Lbs.*	*Lbs.*	*Lbs.*
12 m	......	......	......	......	10.1	5.7	1.8	16.2	......	......
12.15 p.m..	+ ½	2.05	2	−0.75	......	......	......	......	......	......
12.30 p.m..	+ ½	2.05	2	− .85	16	2.1	.0	13.1	......	......
12.45 p.m..	− ½	2.20	2.10	− .90	......	......	......	......	......	......
1 p. m.....	0	2.05	2	− .85	15.2	3	.0	13.8	19,108	19,108
1.15 p. m ..	0	2.05	2	− .85	......	......	......	......	......	......
1.30 p. m ..	+ ½	2.05	2	− .85	10	6.4	1.6	17.1	......	......
1.45 p. m ..	+ ½	2.05	2	− .85	......	......	......	......	......	......
2 p. m.....	− ½	2.05	2	− .85	13.3	5.2	.7	15.5	19,916	39,024
2.15 p. m ..	+ ¾	2.05	2	− .85	......	......	......	......	......	......
2.30 p. m ..	+1½	2.10	2.05	− .85	12.5	5	.9	15.5	......	......
2.45 p. m ..	+ ½	2.05	2	− .85	......	......	......	......	......	......
3 p. m.....	0	2	1.95	− .80	12.6	5	1.1	15.3	20,286	59,310
3.15 p. m ..	0	2.05	2	− .85	......	......	......	......	......	......
3.30 p. m ..	0	2.10	2	− .85	10	6.9	1.6	17.6	......	......
3.45 p. m ..	−2	2	1.95	− .80	......	......	......	......	......	......
4 p. m.....	0	2.05	2	− .80	12.1	4.4	1.3	14.8	20,483	79,794
Average ...	......	2.059	2	− .838	12.42	4.85	1	15.4	19,948	......

Ashes before beginning of test, 195 pounds.
Ashes during test, 459 pounds.
Refuse, including sweepings from tubes and baffles, 815 pounds.
Per cent of moisture in coal by weighing and drying sample, 0.5.

Fired and raked alternately at intervals averaging 9 minutes for each. Average interval between slicings, 14 minutes, varying from 3 minutes to 31 minutes. Frequent flames in stack, especially during first two hours. Average smoke by Ringelmann charts, 2¼.

No. 4.—*Test of Hohenstein water-tube marine boiler, May 29, 1901.*

[Eight hours' duration with natural draft, using coal as a fuel.]

Time.	Steam pressure by gauge.	Temperature of feed water.	Calorimeter.			Air pressures, in inches of water.				
			Higher temperature.	Lower temperature.	Quality of steam.	Ash pit.	Furnace.	Combustion chamber.	Tube chamber.	Base of stack.
	Lbs.	° *F.*	° *F.*	° *F.*						
9 a. m	272	140	399	300	0.982	0.0	—0.20	—0.20	—0.20	—0.20
9.15 a. m...	272	135	402	310	.987	.0	— .20	— .20	— .20	— .22
9.30 a. m...	275	145	404	313	.988	.0	— .18	— .20	— .20	— .22
9.45 a. m...	275	135	402	315	.990	.0	— .16	— .20	— .20	— .22
10 a. m	275	135	403	316	.990	.0	— .18	— .20	— .20	— .20
10.15 a. m..	275	140	404	316	.990	.0	— .18	— .20	— .20	— .20
10.30 a. m..	275	130	406	316	.989	.0	— .16	— .20	— .20	— .20
10.45 a. m..	275	135	406	316	.989	.0	— .18	— .20	— .20	— .20
11 a. m	272	130	403	316	.990	.0	— .16	— .20	— .20	— .20
11.15 a. m..	275	135	404	316	.990	.0	— .16	— .20	— .20	— .22
11.30 a. m..	273	135	402	316	.990	.0	— .16	— .20	— .20	— .22
11.45 a. m..	275	130	403	316	.990	.0	— .18	— .20	— .20	— .22
12 m	270	135	403	317	.990	.0	— .18	— .20	— .20	— .26
12.15 p. m..	272	135	404	318	.990	.0	— .16	— .20	— .20	— .28
12.30 p. m..	272	138	403	317	.990	.0	— .16	— .20	— .20	— .28
12.45 p. m..	272	135	404	317	.990	.0	— .16	— .20	— .20	— .26
1 p. m	272	140	404	317	.990	.0	— .16	— .20	— .20	— .26
1.15 p. m...	272	135	404	317	.990	— .05	— .16	— .20	— .20	— .26
1.30 p. m...	272	135	403	317	.990	— .05	— .18	— .20	— .20	— .28
1.45 p. m...	274	135	403	317	.990	— .05	— .18	— .20	— .20	— .28
2 p. m	270	135	402	317	.991	— .05	— .20	— .22	— .22	— .28
2.15 p. m...	270	140	403	317	.990	.0	— .18	— .20	— .20	— .26
2.30 p. m...	270	145	404	317	.990	.0	— .18	— .20	— .20	— .28
2.45 p. m...	272	142	404	317	.990	.0	— .18	— .20	— .20	— .26
3 p. m	272	140	404	316	.990	.0	— .18	— .20	— .20	— .28
3.15 p.m ...	275	140	406	318	.990	.0	— .16	— .20	— .20	— .26
3.30 p. m...	273	150	404	317	.990	.0	— .16	— .20	— .20	— .24
3.45 p. m...	272	150	404	321	.993	.0	— .18	— .20	— .20	— .24
4 p. m	274	130	404	324	.995	.0	— .18	— .20	— .20	— .26
4.15 p. m...	272	135	403	324	.995	.0	— .20	— .22	— .22	— .28
4.30 p. m...	272	135	403	326	.996	— .02	— .20	— .22	— .22	— .30
4.45 p. m...	274	135	404	330	.998	— .02	— .22	— .25	— .25	— .30
5 p. m	274	130	403	324	.995	— .02	— .20	— .25	— .25	— .28
Average ...	272.8	137	......	......	.990	— .0008	— .177	— .20	— .20	— .24

State of weather, squally.
Barometer at noon, 29.70 inches.
Kind of fuel, Pocahontas coal, run of mine.
Wood burned in starting fires, 340 pounds.
Coal burned in starting fires, 2,000 pounds.
Coal burned during test, 8,633 pounds.
Ashes before beginning of test, 175 pounds.
Ashes during test, 226 pounds.

No. 4.—*Test of Hohenstein water-tube marine boiler, May 29, 1901.*

[Eight hours' duration with natural draft, using coal as a fuel.]

Time.	Height of water in gauge glass.	Temperature.			Flue gases.				Water.	
		Outside air.	Air in fireroom.	Gases at base of stack.	CO_2.	O.	CO.	Dry air per pound carbon.	Fed per hour.	Total weight fed.
	Ins.	° *F.*	° *F.*	° *F.*	*P. ct.*	*P. ct.*	*P. ct.*	*Lbs.*	*Lbs.*	*Lbs.*
9 a. m	0	60	93	......	......	......	......	......	......	......
9.15 a. m..	0	......	95	......	......	......	......	......	......	......
9.30 a. m..	0	......	102	610	13	4	1.5	14.1	......	......
9.45 a. m..	0	......	104	......	......	......	......	......	......	......
10 a. m ...	0	60	104	605	11.2	5.1	1.7	15.4	10,570	10,570
10.15 a. m.	0	......	107	......	......	......	......	......	......	......
10.30 a. m.	0	......	108	610	12.3	4.7	1.6	14.8	......	......
10.45 a. m.	+½	......	111	......	......	......	......	......	......	......
11 a. m ...	0	60	111	610	11.5	6	1.4	16.3	10,252	20,822
11.15 a. m.	0	......	109	......	......	......	......	......	......	......
11.30 a. m.	0	......	111	660	11.2	5.1	1.4	15.6	......	......
11.45 a. m.	0	......	100	......	......	......	......	......	......	......
12 m	0	64	114	660	9.5	5.2	2.8	14.9	10,320	31,142
12.15 p. m.	+½	......	115	......	......	......	......	......	......	......
12.30 p. m.	+½	......	113	665	11.4	3.7	2.6	13.5	......	......
12.45 p. m.	0	......	112	......	......	......	......	......	......	......
1 p. m	0	66	113	655	10.1	7.4	1.2	18.5	9,994	41,136
1.15 p. m..	0	......	112	......	......	......	......	......	......	......
1.30 p. m..	0	......	112	670	10.9	4.5	2.8	14.1	......	......
1.45 p. m..	0	......	111	......	......	......	......	......	......	......
2 p. m	0	66	113	735	9.4	5.3	2.5	15.5	9,653	50,789
2.15 p. m..	0	......	117	......	......	......	......	......	......	......
2.30 p. m..	+½	......	122	665	10.4	4	3.1	13.7	......	......
2.45 p. m..	0	......	124	......	......	......	......	......	......	......
3 p. m	0	70	125	650	11.6	4.9	2	14.9	9,122	59,911
3.15 p. m..	0	......	126	......	......	......	......	......	......	......
3.30 p. m..	0	......	127	665	10.7	3.7	3.3	13.2	......	......
3.45 p. m..	0	......	129	......	......	......	......	......	......	......
4 p. m	+½	66	126	845	11.4	4.4	2	14.5	8,846	68,757
4.15 p. m..	0	......	125	......	......	......	......	......	......	......
4.30 p. m..	0	.....	124	850	11.7	3.5	3	13.1	......	......
4.45 p. m..	0	......	124	......	......	......	......	......	......	......
5 p. m	0	68	125	640	......	......	......	......	9,192	77,949
Average ..	......	64.4	114	675	11.08	4.75	2.19	14.8	9,744	......

Refuse, including sweepings from tubes and baffles, 549 pounds.

Per cent of moisture in coal by chemical analysis, 0.79.

Average interval between firings, six and a half minutes. Average interval between rakings, eight minutes. Average thickness of fire, 6 inches. The draft was checked by means of a damper in the smokepipe, so as to keep the rate of combustion at about 1,100 pounds of coal per hour. Average smoke by Ringelmann charts, 2.2. At 1.40 o'clock two bricks came down from combustion-chamber baffle.

No. 5.—*Test of Hohenstein water-tube marine boiler, June 5, 1901.*

[Six hours' duration with forced draft, using coal as a fuel.]

Time.	Steam pressure by gauge.	Temperature of feed water.	Calorimeter.			Air pressures in inches of water.				
			Higher temperature.	Lower temperature.	Quality of steam.	Fireroom.	Ash pit.	Furnace.	Combustion chamber.	Base of stack.
	Lbs.	° *F.*	° *F.*	° *F.*						
9.30 a. m	275	130	400	304	0.984	1	0.95	0.80	0.60	—0.4
9.45 a. m	270	125	401	304	.984	1	1	.85	.60	— .4
10 a. m	275	125	402	307	.985	1.05	1	.85	.60	— .45
10.15 a. m	275	130	402	309	.987	1.10	1.05	.85	.60	— .45
10.30 a. m	275	130	402	308	.986	1.05	1	.85	.60	— .4
10.45 a. m	275	136	402	309	.987	1	.95	.85	.60	— .4
11 a. m	275	132	400	309	.986	1	.95	.80	.60	— .4
11.15 a. m	272	128	401	310	.987	1	.95	.70	.55	— .4
11.30 a. m	273	130	402	310	.988	1	.95	.75	.60	— .4
11.45 a. m	273	120	402	310	.988	1	.95	.75	.60	— .4
12 m	273	130	402	312	.989	1.10	1.05	.70	.60	— .4
12.15 p. m	275	130	402	311	.988	1.10	1.05	.75	.60	— .4
12.30 p. m	275	130	401	312	.988	1.10	1.05	.85	.65	— .4
12.45 p. m	275	128	402	313	.989	1.10	1.05	.80	.65	— .4
1 p. m	275	130	401	314	.990	1.10	1.05	.85	.65	— .4
1.15 p. m	275	132	402	314	.990	1.10	1.05	.85	.65	— .4
1.30 p. m	275	128	402	313	.989	1.10	1.05	.80	.65	— .4
1.45 p. m	275	134	402	316	.981	1.10	1.05	.80	.65	— .4
2 p. m	275	130	401	317	.992	1.10	1.05	.85	.70	— .4
2.15 p. m	275	130	401	317	.992	1.10	1.05	.80	.65	— .4
2.30 p. m	273	132	401	311	.987	1.10	1.05	.75	.65	— .4
2.45 p. m	273	126	402	314	.990	1.10	1.05	.80	.65	— .4
3 p. m	275	128	403	316	.990	1.10	1.05	.80	.65	— .4
3.15 p. m	272	126	404	317	.990	1.10	1.05	.80	.65	— .4
3.30 p. m	272	132	401	318	.992	1	.95	.75	.60	— .4
Average	274	126.6	.....	......	.988	1.064	1.016	.80	.624	— .404

State of weather, bright and sunshiny.
Barometer at noon, 30.08 inches.
Revolutions of blower, 243 per minute.
Kind of fuel, Pocahontas coal, run of mine.
Wood burned in starting fires, 360 pounds.
Coal burned in starting fires, 2,200 pounds.
Coal burned during test, 10,695 pounds.

No. 5.—*Test of Hohenstein water-tube marine boiler, June 5, 1901.*

[Six hours' duration with forced draft, using coal as a fuel.]

Time.	Height of water in gauge glass.	Temperature.			Flue gases.				Water.	
		Outside air.	Air in fireroom.	Gases at base of stack.	CO₂.	O.	CO.	Dry air per pound carbon.	Fed per hour.	Total weight fed.
	Ins.	° *F.*	° *F.*	° *F.*	*P. ct.*	*P. ct.*	*P. ct.*	*Lbs.*	*Lbs.*	*Lbs.*
9.30 a. m	0	80	118	......	......	......	......	......	......	......
9.45 a. m	−1	......	125	......	......	......	......	......	......	......
10 a. m	0	......	130	730	12.2	4.4	1.6	14.5	......	......
10.15 a. m	0	......	133	......	......	......	......	......	......	......
10.30 a. m	0	82	135	660	10	5.7	2	16.1	15,200	15,200
10.45 a. m	0	......	137	......	......	......	......	......	......	......
11 a. m	+1	......	138	690	11.1	4.3	2.1	14.4	......	......
11.15 a. m	0	......	139	......	......	......	......	......	......	......
11.30 a. m	0	84	139	675	9.7	5.2	2.3	15.4	15,041	30,241
11.45 a. m	0	......	139	......	......	......	......	......	......	......
12 m	0	......	143	675	11	4.3	2	14.5	......	......
12.15 p. m	+½	......	141	......	......	......	......	......	......	......
12.30 p. m	+½	85	140	740	12.2	4.8	1.4	15	16,505	46,746
12.45 p. m	0	......	142	......	......	......	......	......	......	......
1 p. m	+½	......	141	700	10.7	4.8	2.2	14.9	......	......
1.15 p. m	0	......	141	......	......	......	......	......	......	......
1.30 p. m	−1	86	143	700	10	6.6	1.8	17.1	14,914	61,660
1.45 p. m	+1	......	142	......	......	......	......	......	......	......
2 p. m	+½	......	144	670	9.8	4.9	2.7	14.8	......	......
2.15 p. m	+½	......	147	......	......	......	......	......	......	......
2.30 p. m	0	86	146	670	9.4	5.7	2.3	16	15,270	76,930
2.45 p. m	0	......	145	......	......	......	......	......	......	......
3 p. m	0	......	146	745	11.2	4.3	2.1	14.4	......	......
3.15 p. m	0	......	146	......	......	......	......	......	......	......
3.45 p. m	0	86	148	528	6.9	5.4	3.9	15.2	15,534	92,464
Average	......	84.1	139.5	681	10.35	5.03	2.2	15.2	15,411	......

Ashes before beginning test, 200 pounds.
Ashes during test, 1,038 pounds.
Refuse, including sweepings from tubes and baffles, 539 pounds.
Per cent of moisture in coal, by chemical analysis, 0.79.
Fired and raked alternately at intervals averaging 8 minutes for each. Average smoke by Ringelmann charts, 2.2.

No. 6.—*Test of Hohenstein water-tube marine boiler, June 8, 1901.*

[Three and one-half hours' duration with forced draft, using coal as a fuel.]

Time.	Steam pressure by gauge.	Temperature of feed water.	Calorimeter.			Air pressures in inches of water.				
			Higher temperature.	Lower temperature.	Quality of steam.	Fireroom.	Ash pit.	Furnace.	Combustion chamber.	Base of stack.
	Lbs.	° *F.*	° *F.*	° *F.*						
9.30 a. m...	275	112	398	296	0. 980	2	1. 95	1. 50	1. 35	—0. 30
9.45 a. m...	273	118	398	310	. 988	2	1. 90	1. 50	1. 35	— . 30
10 a. m	270	118	398	311	. 989	2	1. 95	1. 55	1. 40	— . 30
10.15 a. m..	272	112	399	309	. 988	2	1. 90	1. 55	1. 40	— . 25
10.30 a. m..	272	110	399	310	. 988	2	1. 95	1. 60	1. 45	— . 20
10.45 a. m..	270	112	399	309	. 988	2	1. 95	1. 60	1. 45	— . 20
11 a. m	270	110	399	306	. 985	2. 1	2	1. 65	1. 45	— . 25
11.15 a. m..	272	108	400	306	. 986	2. 1	2	1. 70	1. 50	— . 15
11.30 a. m..	270	110	399	321	. 995	2. 2.	2. 15	1. 70	1. 50	— . 10
11.45 a. m..	272	112	400	324	. 996	2	2. 05	1. 60	1. 40	— . 15
12 m	275	120	400	319	. 993	1. 95	1. 90	1. 45	1. 30	— . 20
12.15 p. m..	273	130	400	317	. 992	2	1. 95	1. 50	1. 40	— . 30
12.30 p. m..	272	130	400	324	. 996	2	1. 95	1. 45	1. 40	— . 30
12.45 p. m..	272	130	401	329	. 999	2	1. 95	1. 50	1. 45	— . 30
1 p. m	......	......	399	328	. 998	......	......	......	......	......
Average ...	272	116. 5	......	......	. 990	2. 025	1. 968	1. 56	1. 41	— . 235

State of weather, bright and sunshiny.
Barometer at noon, 29.95 inches.
Revolutions of blower, 875 per minute.
Kind of fuel, Pocahontas coal, run of mine.
Coal burned during test, 8,736—275=8, 461 pounds.
Ashes during test, 591 pounds.

No. 6.—*Test of Hohenstein water-tube marine boiler, June 8, 1901.*

[Three and one-half hours' duration with forced draft, using coal as a fuel.]

Time.	Height of water in gauge glass.	Temperature.			Flue gases.				Water.	
		Outside air.	Air in fireroom.	Gases at base of stack.	CO$_2$.	O.	CO.	Dry air per pound carbon.	Fed per hour.	Total weight fed.
	Ins.	° *F.*	° *F.*	° *F.*	*P. ct.*	*P. ct.*	*P. ct.*	*Lbs.*	*Lbs.*	*Lbs.*
9.30 a. m.	0	70	106	......	......	......	......	......	......	......
9.45 a. m.	0	......	116	......	......	......	......	......	......	......
10 a. m.	0	......	120	840	13	......	2.2	......	......	......
10.15 a. m.	0	......	120	......	......	......	......	......	......	......
10:30 a. m.	0	76	124	930	10.5	3.9	1.9	14.3	17,641	17,641
10.45 a. m.	0	......	124	......	......	......	......	......	......	......
11 a. m	0	......	124	800	11.8	4.9	1.3	15.3	......	......
11.15 a. m.	0	......	128	......	......	......	......	......	......	......
11.30 a. m.	0	76	131	1,450	17.8	.7	.1	12	17,521	35,162
11.45 a. m.	0	......	132	......	......	......	......	......	......	......
12 m	+ ½	......	133	1,240	16.7	1.7	.2	12.6	......	......
12.15 p. m.	0	......	134	......	......	......	......	......	......	......
12:30 p. m.	0	77	137	1,060	16.6	2.4	.1	13.2	16,648	51,810
12.45 p. m.	0	......	140	......	......	......	......	......	......	......
1 p. m	0	......	141	1,560	10	8.8	.7	20.6	8,729	60,539
Average	......	74.75	127.3	1,125.7	13.77	3.73	.928	14.66	17,297	......

Refuse, including sweepings from tubes and baffles, 626 pounds.

Per cent of moisture in coal by chemical analysis, 0.79.

Fired and raked alternately at intervals averaging 6 minutes for each. Average smoke by Ringelmann charts, 3.4. Almost continual flaming in stack. Base of stack occasionally red hot. Test stopped prematurely at 1 o'clock on account of roof taking fire. The fires were about 2 inches thicker at end of trial than at beginning, corresponding to a difference of about 275 pounds of coal.

No. 7.—*Test of Hohenstein water-tube marine boiler, October 21, 1901.*

[Eight hours' duration with natural draft, using coal as a fuel.]

Time.	Steam pressure by gauge.	Temperature of feed water.	Calorimeter.			Air pressures in inches of water.				
			Higher temperature.	Lower temperature.	Quality of steam.	Ash pit.	Furnace.	Combustion chamber.	Tube chamber.	Base of stack.
	Lbs.	° *F.*	° *F.*	° *F.*						
8.30 a. m.	......	......	404	306	0.984	......	......	......	......	......
8.45 a. m.	275	126	404	307	.985	—0.05	—0.10	—0.07	—0.15	—0.50
9 a. m.	275	124	404	307	.985	— .05	— .10	— .06	— .20	— .50
9.15 a. m.	275	124	404	309	.986	— .05	— .10	— .06	— .20	— .50
9.30 a. m.	275	128	404	309	.986	— .05	— .10	— .06	— .20	— .50
9.45 a. m.	275	124	404	309	.986	— .05	— .10	— .06	— .20	— .50
10 a. m.	275	126	404	309	.986	— .05	— .10	— .06	— .20	— .50
10.15 a. m.	275	128	404	309	.986	— .05	— .12	— .08	— .22	— .50
10.30 a. m.	275	130	404	310	.986	— .05	— .14	— .08	— .22	— .50
10.45 a. m.	275	128	404	310	.986	— .05	— .16	— .10	— .24	— .50
11 a. m.	275	128	404	310	.986	— .05	— .16	— .10	— .24	— .50
11.15 a. m.	275	126	404	310	.986	— .05	— .16	— .10	— .24	— .50
11.30 a. m.	275	126	404	310	.986	— .05	— .16	— .08	— .22	— .50
11.45 a. m.	275	134	404	310	.986	— .05	— .16	— .12	— .24	— .50
12 m.	275	134	404	310	.986	— .05	— .18	— .12	— .22	— .50
12.15 p. m.	275	128	403	310	.987	— .05	— .18	— .12	— .22	— .50
12.30 p. m.	275	130	404	310	.986	— .05	— .18	— .14	— .22	— .50
12.45 p. m.	275	130	404	310	.986	— .05	— .18	— .14	— .22	— .50
1 p. m.	275	130	404	312	.987	— .05	— .18	— .14	— .22	— .50
1.15 p. m.	275	132	404	311	.987	— .05	— .20	— .14	— .22	— .50
1.30 p. m.	275	134	404	312	.987	— .05	— .20	— .14	— .22	— .50
1.45 p. m.	275	132	404	311	.987	— .05	— .18	— .14	— .22	— .50
2 p. m.	275	130	404	310	.986	— .05	— .20	— .14	— .22	— .50
2.15 p. m.	275	134	402	311	.988	— .05	— .18	— .14	— .22	— .50
2.30 p. m.	275	134	404	311	.987	— .05	— .18	— .15	— .22	— .50
2.45 p. m.	275	136	404	310	.986	— .05	— .18	— .15	— .22	— .50
3 p. m.	275	138	404	310	.986	— .05	— .16	— .15	— .22	— .50
3.15 p. m.	275	140	404	310	.986	— .05	— .16	— .15	— .22	— .50
3.30 p. m.	275	140	404	310	.986	— .05	— .16	— .15	— .22	— .50
3.45 p. m.	275	140	404	311	.987	— .05	— .16	— .15	— .22	— .50
4 p. m.	275	142	404	311	.987	— .05	— .16	— .15	— .22	— .50
4.15 p. m.	275	140	404	312	.988	— .05	— .14	— .14	— .20	— .50
4.30 p. m.	275	142	404	312	.988	— .05	— .14	— .14	— .20	— .50
Average	275	131.8	......	......	.986	— .05	— .155	— .116	— .216	— .50

State of weather, clear.
Barometer at noon, 30.34 inches.
Kind of fuel, New River coal, run of mine.
Wood burned in starting fires, 360 pounds.
Coal burned in starting fires, 2,000 pounds.
Ashes before beginning test, 198 pounds.
Ashes during test, 485 pounds.

No. 7.—*Test of Hohenstein water-tube marine boiler, October 21, 1901.*

[Eight hours' duration with natural draft, using coal as a fuel.]

Time.	Height of water in gauge glass.	Temperature.			Flue gases.				Coal fired per hour.	Water fed per hour.
		Outside air.	Air in fireroom.	Gases at base of stack.	CO_2.	O.	CO.	Dry air per pound carbon.		
	Ins.	° *F.*	° *F.*	° *F.*	*P. ct.*	*P. ct.*	*P. ct.*	*Lbs.*	*Lbs.*	*Lbs.*
8.30 a. m...	2½	......	110	......	......	......	......	......	......	......
8.45 a. m...	2½	60	117	540	9.7	6.2	1.1	17.5	......	......
9 a. m	2½	......	117	......	......	......	......	......	......	......
9.15 a. m...	2	......	121	555	10	5.8	1.1	17	......	......
9.30 a. m...	2	......	126	......	......	......	......	......	1,300	9,534
9.45 a. m...	2	66	130	535	10.1	5.6	2	15.9	......	......
10 a. m	2	......	137	......	......	......	......	......	......	......
10.15 a. m..	2½	......	137	570	9.5	5.7	2.1	16.2	......	......
10.30 a. m..	2	......	138	......	......	......	......	......	1,175	9,554
10.45 a. m..	2¼	68	140	575	10	6.5	1.1	17.7	......	......
11 a. m	2	......	143	......	......	......	......	......	......	......
11.15 a. m..	2	......	141	560	10	5.7	1.8	16.2	......	......
11.30 a. m..	2½	......	144	......	......	......	......	......	1,125	9,693
11.45 a. m..	2	72	148	581	10.2	6.2	1.6	16.8	......	......
12 m	2	......	143	......	......	......	......	......	......	......
12.15 p. m .	2½	......	148	560	9.2	7.4	1.2	19.1	......	......
12.30 p. m .	2½	......	148	......	......	......	......	......	1,100	9,058
12.45 p. m .	2½	74	147	584	9.2	6.8	1.7	17.8	......	......
1 p. m.....	2¾	......	144	......	......	......	......	......	......	......
1.15 p. m ..	2½	......	148	550	9.2	6.8	1.8	17.7	......	......
1.30 p. m ..	2¾	......	144	......	......	......	......	......	1,100	8,660
1.45 p. m ..	2¾	76	150	560	9.1	7.7	1	19.7	......	......
2 p. m.....	2¾	......	143	......	......	......	......	......	......	......
2.15 p. m ..	2½	......	150	560	8.7	6.8	2.3	17.5	......	......
2.30 p. m ..	2½	......	158	......	......	......	......	......	1,000	8,381
2.45 p. m ..	2¾	76	162	570	8.5	6.1	1.6	17.6	......	......
3 p. m.....	2¾	......	164	......	......	......	......	......	......	......
3.15 p. m ..	2¾	......	160	565	8	6.4	1.8	18	......	......
3.30 p. m ..	2½	......	159	......	......	......	......	......	650	7,217
3.45 p. m ..	2½	78	162	570	8.8	6.7	1.2	18.5	......	......
4 p. m.....	2½	......	160	......	......	......	......	......	......	......
4.15 p. m ..	3	......	156	565	8	7.3	.9	20.4	......	......
4.30 p. m ..	3	......	155	......	......	......	......	......	605	6,475
Average		71¼	144	562½	9.26	6.48	1.52	17.7	1,007	8,558

Refuse, including sweepings from tubes and baffles, 561 pounds.

Per cent of moisture in coal by weighing and drying samples, 3.14.

Average interval between firings, 6 minutes. Raked and sliced alternately between firings. Thickness of fire during first four hours, 6 inches; for next two hours, 9 inches; then allowed to burn down to original thickness. Average smoke by Ringelmann charts, 2.

Total weight of coal fired, 8,055 pounds.

Total weight of water fed, 68,572 pounds.

No. 8.—*Test of Hohenstein water-tube marine boiler, October 23, 1901.*

[Six hours' duration with forced draft, using coal as a fuel.]

Time.	Steam pressure by gauge.	Temperature of feed water.	Calorimeter.			Air pressure in inches of water.					
			Higher temperature.	Lower temperature.	Quality of steam.	Fireroom.	Ash pit.	Furnace.	Combustion chamber.	Tube chamber.	Base of stack.
	Lbs.	° *F.*	° *F.*	° *F.*							
9 a. m.	......	......	......	......	......	......	......	......	......	......	......
9.15 a. m.	275	128	403	292	0.976	1	0.95	0.80	0.70	0.45	−0.50
9.30 a. m.	275	130	402	292	.977	1.05	.95	.78	.70	.50	−.47
9.45 a. m.	275	120	402	295	.979	1.05	1	.70	.65	.45	−.45
10 a. m.	275	120	402	292	.977	1.05	1	.75	.70	.48	−.42
10.15 a. m.	275	118	402	292	.977	1.05	1	.75	.70	.45	−.45
10.30 a. m.	275	119	402	293	.977	1.05	1	.75	.68	.45	−.43
10.45 a. m.	275	124	402	292	.977	1.05	1	.80	.70	.50	−.45
11 a. m.	275	120	402	293	.977	1.08	1	.75	.70	.50	−.45
11.15 a. m.	275	129	402	296	.979	1.08	1	.80	.70	.50	−.43
11.30 a. m.	275	122	402	292	.977	1.08	1	.80	.70	.50	−.45
11.45 a. m.	275	126	402	290	.976	1.05	1	.80	.70	.50	−.45
12 m.	275	128	402	290	.976	1.08	1	.82	.75	.55	−.42
12.15 p. m.	275	126	402	292	.977	1.10	1	.85	.72	.55	−.45
12.30 p. m.	275	122	402	292	.977	1.10	1	.85	.72	.55	−.48
12.45 p. m.	275	128	402	291	.976	1.10	1	.85	.76	.58	−.45
1 p. m.	275	126	401	289	.976	1.10	1	.85	.75	.55	−.50
1.15 p. m.	275	124	402	290	.976	1.08	1	.85	.75	.55	−.50
1.30 p. m.	275	122	402	289	.975	1.08	1	.85	.75	.55	−.50
1.45 p. m.	275	126	402	289	.975	1.08	1	.85	.75	.55	−.48
2 p. m.	275	132	402	291	.976	1.05	1	.85	.75	.55	−.48
2.15 p. m.	275	136	402	288	.975	1.08	1	.85	.75	.55	−.48
2.30 p. m.	275	132	402	288	.975	1.08	1	.85	.75	.55	−.48
2.45 p. m.	275	130	402	288	.975	1.10	1.05	.85	.75	.50	−.48
3 p. m.	275	138	402	288	.975	1.10	1.05	.85	.75	.50	−.48
Average	275	126.1	.....	.....	.976	1.07	1	.813	.722	.515	−.464

State of weather, cloudy.
Barometer at noon, 29.95 inches.
Kind of fuel, New River coal, run of mine.
Wood burned in starting fires, 250 pounds.
Coal burned in starting fires, 1,910 pounds.
Ashes before beginning test, 161 pounds.
Ashes during test, 365 pounds.

No. 8.—*Test of Hohenstein water-tube marine boiler, October 23, 1901.*

[Six hours' duration with forced draft, using coal as a fuel.]

Time.	Height of water in gauge glass.	Temperature.			Flue gases.				Coal fired per hour.	Water fed per hour.
		Outside air.	Air in fireroom.	Gases at base of stack.	CO_2.	O.	CO.	Dry air per pound carbon.		
	Ins.	° *F.*	° *F.*	° *F.*	*Per ct.*	*Per ct.*	*Per ct.*	*Lbs.*	*Lbs.*	*Lbs.*
9 a. m	2½		106							
9.15 a. m	2½	70	111	630	8.6	7.3	1.5	19		
9.30 a. m	2½		114							
9.45 a. m	2¾		116	637	8.9	7	2.1	17.8		
10 a. m	2½		118						2,000	13,996
10.15 a. m	2½	72	118	670	9	6.5	1.5	17.8		
10.30 a. m	2½		123							
10.45 a. m	2½		120	630	7.7	7	2.9	17.6		
11 a. m	2½		123						1,800	14,508
11.15 a. m	3	76	128	680	9	6.3	1.9	17.2		
11.30 a. m	2¾		124							
11.45 a. m	2½		124	678	8.6	7.2	1.1	19.5		
12 m	2¾		128						1,800	14,344
12.15 p. m	3	76	125	667	9.5	6.7	1.6	17.7		
12.30 p. m	3		127							
12.45 p. m	3		128	660	9.5	6.6	1.3	17.9		
1 p. m	2½		130						1,600	14,194
1.15 p. m	2¾	76	129	660	10	6.6	1.1	17.8		
1.30 p. m	3		128							
1.45 p. m	4		128	680	9	7.2	1.6	18.5		
2 p. m	3		124						1,400	13,459
2.15 p. m	2½	76	127	635	9.1	8.3	.6	21		
2.30 p. m	2½		131							
2.45 p. m	2½		131	620	7.5	6.6	1.9	18.5		
3 p. m	2½		126						1,098	10,246
Average		74.34	123.5	654	8.87	6.94	1.59	18.4	1,616	13,458

Refuse, including sweepings from tubes and baffles, 528 pounds.
Per cent of moisture in coal by weighing and drying sample, 3.14.
Average interval between firings, six minutes. Raked and sliced alternately between firings. Occasional flames in stack. Average smoke by Ringelmann charts, 2.
Total weight of coal fired, 9,698 pounds.
Total weight of water fed, 80,747 pounds.

No. 9.—*Test of Hohenstein water-tube marine boiler, October 26, 1901.*

[Four hours' duration with forced draft, using coal as a fuel.]

Time.	Steam pressure by gauge.	Temperature of feed water.	Calorimeter.			Air pressures in inches of water.					
			Higher temperature.	Lower temperature.	Quality of steam.	Fireroom.	Ash pit.	Furnace.	Combustion chamber.	Tube chamber.	Base of stack.
	Lbs.	° *F.*	° *F.*	° *F.*							
12.45 p. m.	275	......	396	290	0.978	......	....	......	......	......	......
1 p. m.....	275	112	397	292	.979	2.10	2	1.40	1.25	1.05	—0.90
1.15 p. m..	275	110	397	294	.980	2.10	2	1.45	1.25	1.05	— .95
1.30 p. m..	275	110	397	292	.979	2.10	2	1.45	1.25	1.10	— .95
1.45 p. m..	275	112	397	297	.982	2.10	2	1.45	1.30	1.15	—1
2 p. m.....	275	112	397	294	.980	2.10	2	1.45	1.30	1.15	— .95
2.15 p. m..	275	116	397	296	.981	2.10	2	1.45	1.30	1.10	—1
2.30 p. m..	275	112	397	294	.980	2.10	2	1.45	1.25	1.10	—1
2.45 p. m..	275	112	397	296	.981	2.10	2	1.45	1.25	1.10	—1
3 p. m.....	275	112	397	293	.979	2.10	2	1.45	1.25	1.10	—1
3.15 p. m..	275	112	397	292	.979	2.10	2	1.40	1.20	1.05	—1
3.30 p. m..	275	112	397	294	.980	2.10	2	1.40	1.20	1.05	—1
3.45 p. m..	275	110	397	293	.979	2.10	2	1.40	1.20	1.05	—1
4 p. m.....	275	110	397	292	.979	2.10	2	1.40	1.22	1.05	—1
4.15 p. m..	275	112	397	292	.978	2.10	2	1.40	1.22	1.05	—1
4.30 p. m..	275	112	397	291	.978	2.10	2	1.40	1.25	1.10	—1
4.45 p. m..	275	112	397	294	.980	2.10	2	1.40	1.25	1.10	—1
Average...	275	111.75	.....	.....	.980	2.10	2	1.43	1.25	1.08	— .98

State of weather, smoky.
Barometer at noon, 30.25 inches.
Kind of fuel, New River coal—run of mine.
Wood burned in starting fires, 361 pounds.
Coal burned in starting fires, 2,200 pounds.

No. 9.—*Test of Hohenstein water-tube marine boiler, October 26, 1901.*

[Four hours' duration with forced draft, using coal as a fuel.]

Time.	Height of water in gauge glass.	Temperature.			Flue gases.				Coal fired per hour.	Water fed per hour.
		Outside air.	Air in fireroom.	Gases at base of stack.	CO_2.	O.	CO.	Dry air per pound carbon.		
	Ins.	° *F.*	° *F.*	° *F.*	*P. ct.*	*P. ct.*	*P. ct.*	*Lbs.*	*Lbs.*	*Lbs.*
12.45 p. m.	2½	......	102	......	......	......	......	......	......	......
1 p. m.	2	......	102	685	7.5	6.3	2.4	17.1	......	......
1.15 p. m.	2	......	102	......	......	......	......	......	......	......
1.30 p. m.	4	......	104	713	8.3	6.7	1.5	18.1	......	......
1.45 p. m.	2¾	68	104	......	......	......	......	......	2,450	18,147
2 p. m.	2¼	......	105	750	10	5.9	1.9	16.4	......	......
2.15 p. m.	2	......	108	......	......	......	......	......	......	......
2.30 p. m.	2½	......	110	650	9.6	6.4	1.4	17.5	......	......
2.45 p. m.	3	68	108	......	......	......	......	......	2,350	18,662
3 p. m.	2¾	......	110	732	9.2	6.5	1.7	17.5	......	......
3.15 p. m.	2¾	......	108	......	......	......	......	......	......	......
3.30 p. m.	2¾	......	109	605	9.4	6.3	2	16.9	......	......
3.45 p. m.	2¾	68	109	......	......	......	......	......	2,300	18,196
4 p. m.	3	......	108	725	9.8	6.8	1	18.2	......	......
4.15 p. m.	3¾	......	108	......	......	......	......	......	......	......
4.30 p. m.	2½	......	107	640	10	6	1.4	16.9	......	......
4.45 p. m.	2½	68	106	......	......	......	......	......	1,900	16,639
Average	......	68	106.5	687.5	9.2	6.4	1.7	17.3	2,250	17,911

Ashes before beginning test, 152 pounds.
Ashes during test, 391 pounds.
Refuse, including sweepings from tubes and baffles, 732 pounds.
Per cent of moisture in coal by weighing and drying sample, 3.14.
Average interval between firings, 6 minutes. Raked and sliced alternately between firings. Frequent fires in stack. Average smoke by Ringelmann charts, ¼.
Total pounds of coal fired, 9,000.
Total pounds of water fed, 71,644.

No. 10.—*Test of Hohenstein water-tube marine boiler, November 6, 1901.*

[Eight hours' duration with natural draft.]

Time.	Steam pressure by gauge.	Temperature of feed water.	Calorimeter.			Air pressures in inches of water.				
			Higher temperature.	Lower temperature.	Quality of steam.	Ash pit.	Furnace.	Combustion chamber.	Tube chamber.	Base of stack.
	Lbs.	° *F.*	° *F.*	° *F.*						
8.45 a. m.	275	120	402	302	0.983	—0.05	—0.10	—0.10	—0.10	—0.50
9 a. m.	275	124	402	306	.985	— .05	— .10	— .12	— .10	— .50
9.15 a. m.	275	120	402	314	.990	— .05	— .10	— .12	— .10	— .50
9.30 a. m.	275	126	402	316	.991	— .05	— .10	— .12	— .15	— .50
9.45 a. m.	275	126	402	311	.988	— .05	— .12	— .12	— .20	— .50
10 a. m.	275	119	402	326	.997	— .05	— .14	— .12	— .20	— .50
10.15 a. m.	275	127	402	326	.997	— .05	— .20	— .14	— .20	— .50
10.30 a. m.	275	120	404	330	.998	— .05	— .20	— .15	— .20	— .50
10.45 a. m.	275	129	402	313	.989	— .05	— .17	— .15	— .20	— .50
11 a. m.	275	119	402	312	.989	— .05	— .18	— .15	— .20	— .50
11.15 a. m.	275	124	402	310	.987	— .05	— .15	— .15	— .20	— .50
11.30 a. m.	275	126	402	312	.988	— .05	— .20	— .15	— .20	— .50
11.45 a. m.	275	124	402	310	.987	— .05	— .18	— .15	— .20	— .50
12 m.	275	126	402	310	.987	— .05	— .18	— .15	— .20	— .50
12.15 p. m.	275	130	402	308	.986	— .05	— .15	— .15	— .20	— .50
12.30 p. m.	275	126	402	312	.988	— .05	— .20	— .15	— .20	— .50
12.45 p. m.	275	130	403	309	.986	— .05	— .20	— .15	— .20	— .50
1 p. m.	275	130	406	311	.986	— .05	— .20	— .15	— .20	— .50
1.15 p. m.	275	124	403	314	.989	— .05	— .18	— .16	— .20	— .50
1.30 p. m.	275	126	402	313	.989	— .05	— .15	— .16	— .20	— .50
1.45 p. m.	275	130	403	310	.987	— .05	— .15	— .15	— .20	— .50
2 p. m.	275	126	402	311	.988	— .05	— .14	— .15	— .20	— .50
2.15 p. m.	275	140	402	310	.987	— .05	— .14	— .15	— .20	— .50
2.30 p. m.	275	120	402	309	.987	— .05	— .14	— .15	— .20	— .50
2.45 p. m.	275	130	403	309	.986	— .05	— .14	— .14	— .20	— .50
3 p. m.	275	130	402	310	.987	— .05	— .15	— .14	— .20	— .50
3.15 p. m.	275	122	402	310	.987	— .05	— .15	— .15	— .20	— .50
3.30 p. m.	275	134	402	310	.987	— .05	— .15	— .15	— .20	— .50
3.45 p. m.	275	126	402	310	.987	— .05	— .15	— .15	— .20	— .50
4 p. m.	275	124	402	311	.988	— .05	— .15	— .15	— .20	— .50
4.15 p. m.	275	125	402	310	.987	— .05	— .12	— .15	— .20	— .50
4.30 p. m.	275	129	402	308	.986	— .05	— .12	— .12	— .20	— .50
4.45 p. m.	275	124	402	310	.987	— .05	— .12	— .12	— .20	— .50
Average	275	125.94	.....	.....	.988	— .05	— .15	— .14	— .19	— .50

State of weather, clear and humid.
Barometer at noon, 30.20 inches.
Kind of fuel, Pocahontas coal, hand picked and screened.
Wood burned in starting fires, 350 pounds.
Coal burned in starting fires, 2,792 pounds.
Ashes before beginning test, 225 pounds.

No. 10.—*Test of Hohenstein water-tube marine boiler, November 6, 1901.*

[Eight hours' duration with natural draft.]

Time.	Height of water in gauge glass.	Temperature.			Flue gases.		Coal.		Water.	
		Outside air.	Air in fireroom.	Gases at base of stack.	CO_2.	Dry air per pound carbon.	Fired per hour.	Total weight fired.	Fed per hour.	Total weight fed.
	Ins.	*° F.*	*° F.*	*° F.*	*Per ct.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*
8.45 a. m	2½	62	111	525	11.1	14.7	......	......	......	......
9 a. m	2¾	......	110	......	......	......	......	......	......	......
9.15 a. m	2½	......	118	580	9.5	14.5	......	......	......	......
9.30 a. m	2¾	......	120	......	......	......	......	......	......	......
9.45 a. m	2¼	66	118	590	9.9	15	1,582	1,582	9,251	9,251
10 a. m	3	......	120	......	......	......	......	......	......	......
10.15 a. m	2½	......	122	600	10	15.3	......	......	......	......
10.30 a. m	2¾	......	124	......	......	......	......	......	......	......
10.45 a. m	2¼	62	128	560	9.5	15.6	988	2,570	9,843	19,094
11 a. m	2½	......	129	......	......	......	......	......	......	......
11.15 a. m	2½	......	124	540	9.6	16.1	......	......	......	......
11.30 a. m	2½	......	125	......	......	......	......	......	......	......
11.45 a. m	2½	60	126	500	8.8	16.3	1,060	3,630	9,518	28,612
12 m	2½	......	124	......	......	......	......	......	......	......
12.15 p. m	2½	......	126	635	9	16.7	......	......	......	......
12.30 p. m	2½	......	127	......	......	......	......	......	......	......
12.45 p. m	2½	63	124	575	8.9	15.2	1,114	4,744	8,931	37,543
1 p. m	2¾	......	121	......	......	......	......	......	......	......
1.15 p. m	2½	......	126	680	10.2	15.2	......	......	......	......
1.30 p. m	2½	......	124	......	......	......	......	......	......	......
1.45 p. m	2½	63	127	490	7.6	16.6	888	5,632	8,961	46,504
2 p. m	2½	......	127	......	......	......	......	......	......	......
2.15 p. m	2¼	......	129	495	7.1	18.5	......	......	......	......
2.30 p. m	2¼	......	131	......	......	......	......	......	......	......
2.45 p. m	2½	64	132	510	7.6	16.1	890	6,522	7,906	54,410
3 p. m	2½	......	126	......	......	......	......	......	......	......
3.15 p. m	2¾	......	130	495	8.8	15.4	......	......	......	......
3.30 p. m	2½	......	130	......	......	......	......	......	......	......
3.45 p. m	2½	63	130	527	6.3	16.8	838	7,360	7,984	62,394
4 p. m	2¾	......	134	......	......	......	......	......	......	......
4.15 p. m	2½	......	134	500	8.8	15.5	......	......	......	......
4.30 p. m	2½	......	132	......	......	......	......	......	......	......
4.45 p. m	2½	61	130	520	8.4	15.6	939	8,299	7,754	70,148
Average	......	62.7	125	548.4	8.89	15.8	1,037	......	8,769	......

Ashes during test, 214 pounds.

Refuse, including sweepings from tubes and baffles, 526 pounds.

Per cent of moisture in coal by weighing and drying sample, 2.04.

Fired every 6 minutes. Raked after each second firing. Sliced at intervals of about 20 minutes, 8.45 to 10.45, thick fires and frequent flames in stack. 10.45 to end of test, thin fires and little or no flaming in stack. One calorimeter out of order. Smoke by Ringelmann charts, 1.

Total weight of coal burned, 8,299 pounds.

Total weight of water fed, 70,148 pounds.

No. 11.—*Test of Hohenstein water-tube marine boiler, November 9, 1901.*

[Eight hours' duration with natural draft.]

Time.	Steam pressure by gauge.	Temperature of feed water.	Calorimeter.			Air pressures in inches of water.				
			Higher temperature.	Lower temperature.	Quality of steam.	Ash pit.	Furnace.	Combustion chamber.	Tube chamber.	Base of stack.
	Lbs.	° *F.*	° *F.*	° *F.*						
8.45 a. m...	275	122	402	300	0.981	−0.05	−0.08	−0.08	−0.10	−0.50
9 a. m......	275	106	403	302	.982	− .05	− .08	− .08	− .10	− .55
9.15 a. m...	275	124	403	304	.983	− .05	− .08	− .08	− .10	− .55
9.30 a. m...	275	120	403	305	.984	− .05	− .08	− .08	− .10	− .55
9.45 a. m...	275	128	403	306	.984	− .05	− .08	− .08	− .10	− .55
10 a. m.....	275	127	403	307	.985	− .05	− .08	− .08	− .10	− .55
10.15 a. m..	275	124	404	308	.985	− .05	− .08	− .08	− .10	− .55
10.30 a. m..	275	118	403	310	.986½	− .05	− .08	− .08	− .10	− .55
10.45 a. m..	275	130	403	311	.987	− .05	− .08	− .08	− .10	− .55
11 a. m.....	275	123	404	312	.987½	− .05	− .08	− .08	− .10	− .55
11.15 a. m..	275	125	404	312	.987½	− .05	− .10	− .10	− .12	− .55
11.30 a. m..	275	123	403	312	.988	− .05	− .10	− .10	− .12	− .55
11.45 a. m..	275	125	403	312	.987½	− .05	− .10	− .10	− .12	− .55
12 m.......	275	120	403	312	.988	− .05	− .10	− .10	− .12	− .55
12.15 p. m.	275	126	403	312	.987½	− .05	− .10	− .10	− .12	− .55
12.30 p. m.	275	112	403	313	.988	− .05	− .10	− .10	− .12	− .55
12.45 p. m.	275	126	402	313	.989	− .05	− .10	− .10	− .12	− .55
1 p. m.....	275	113	402	314	.989½	− .05	− .10	− .10	− .12	− .55
1.15 p. m..	275	124	403	313	.987½	− .05	− .10	− .10	− .12	− .55
1.30 p. m..	275	118	403	314	.989	− .05	− .10	− .10	− .12	− .55
1.45 p. m..	275	132	403	314	.989	− .05	− .10	− .10	− .12	− .55
2 p. m.....	275	120	403	314	.989	− .05	− .10	− .10	− .12	− .55
2.15 p. m..	275	130	404	314	.988½	− .05	− .10	− .10	− .12	− .55
2.30 p. m..	275	122	403	314	.989	− .05	− .10	− .10	− .12	− .55
2.45 p. m..	275	128	403	314	.989	− .05	− .10	− .10	− .12	− .55
3 p. m.....	275	117	403	314	.989	− .05	− .10	− .10	− .12	− .55
3.15 p. m..	275	122	403	314	.989	− .05	− .10	− .10	− .12	− .55
3.30 p. m..	275	122	404	314	.988½	− .05	− .10	− .10	− .12	− .55
3.45 p. m..	275	122	404	314	.988½	− .02	− .10	− .10	− .12	− .55
4 p. m.....	275	118	404	314	.988½	− .02	− .10	− .10	− .12	− .55
4.15 p. m..	275	123	404	314	.988½	− .02	− .10	− .10	− .12	− .55
4.30 p. m..	275	123	403	314	.989	− .02	− .10	− .10	− .12	− .55
4.45 p. m..	275	124	404	316	.990	− .02	− .10	− .10	− .12	− .55
Average ...	275	122.3	.....	......	.987	− .045	− .094	− .094	− .114	− .548

State of weather, cloudy, occasional sun.
Barometer at noon, 30.18 inches.
Kind of fuel, Pocahontas coal, hand picked and screened.
Wood burned in starting fires, 350 pounds.
Coal burned in starting fires, 1,435 pounds.

No. 11.—*Test of Hohenstein water-tube marine boiler, November 9, 1901.*

[Eight hours' duration with natural draft.]

Time.	Height of water in gauge glass.	Temperature.			Flue gasses.		Coal.		Water.	
		Outside air.	Air in fireroom.	Gases at base of stack.	CO₂.	Dry air per pound carbon.	Fired per hour.	Total weight fired.	Fed per hour.	Total weight fed.
	Ins.	° *F.*	° *F.*	° *F.*	*Per ct.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*
8.45 a. m...	2½	44	92	......	......	......	......	......	......	......
9 a. m......	2½	......	88	512	9.4	15.1	......	......	......	......
9.15 a. m...	2½	......	88	......	......	......	......	......	......	......
9.30 a. m...	2½	......	94	515	7.6	15.6	......	......	......	......
9.45 a. m...	2¾	52	98	......	......	......	938	938	8,455	8,455
10 a. m.....	2¾	......	107	512	5.3	16.9	......	......	......	......
10.15 a. m..	2¾	......	108	......	......	......	......	......	......	......
10.30 a. m..	2¾	......	120	485	6.2	16.3	......	......	......	......
10.45 a. m..	2¾	52	120	......	......	......	937	1,875	7,067	15,522
11 a. m.....	2¾	......	130	505	8.4	15.9	......	......	......	......
11.15 a. m..	2½	......	126	......	......	......	......	......	......	......
11.30 a. m..	2½	......	122	510	6.9	16.4	......	......	......	......
11.45 a. m..	2½	55	126	......	......	......	937	2,812	7,673	23,195
12 m.......	2¾	......	129	515	8.8	15.3	......	......	......	......
12.15 p. m .	2½	......	128	......	......	......	......	......	......	......
12.30 p. m .	3	......	132	530	8.9	15	......	......	......	......
12.45 p. m .	2¼	59	138	......	......	......	1,014	3,826	8,768	31,963
1 p. m	3	......	136	560	9.3	14.9	......	......	......	......
1.15 p. m ..	2½	......	135	......	......	......	......	......	......	......
1.30 p. m ..	2¾	......	128	530	7.4	15	......	......	......	......
1.45 p. m ..	2½	57	142	......	......	......	968	4,794	8,772	40,735
2 p. m	2¾	......	140	520	8.6	15.8	......	......	......	......
2.15 p. m ..	2½	......	138	......	......	......	......	......	......	......
2.30 p. m ..	2¾	......	136	540	9.4	14.4	......	......	......	......
2.45 p. m ..	2½	57	132	......	......	......	940	5,734	8,453	49,188
3 p. m	2½	......	132	525	8.1	15.3	......	......	......	......
3.15 p. m ..	2¾	......	138	......	......	......	......	......	......	......
3.30 p. m ..	2¾	......	136	525	7	15.8	......	......	......	......
3.45 p. m ..	2½	60	136	......	......	......	888	6,622	8,079	57,267
4 p. m	2½	......	139	523	8	15.3	......	......	......	......
4.15 p. m ..	2½	......	137	......	......	......	......	......	......	......
4.30 p. m ..	2½	......	142	527	8.6	15.5	......	......	......	......
4.45 p. m ..	2½	60	144	......	......	......	814	7,436	8,163	65,430
Average ...	......	55.1	125.4	521	8	15.15	930	......	8,179	......

Ashes before beginning test, 303 pounds.
Ashes during test, 584 pounds.
Refuse, including sweepings from tubes and baffles, 356 pounds.
Per cent of moisture in coal by weighing and drying sample, 1.15.
Fired every 6 minutes. Raked after each second firing. No slicing until last two hours, then twice each hour. Fires thin. No flaming in stack. Very little smoke; none except while firing.
Total weight of coal fired, 7,436 pounds.
Total weight of water fed, 65,430 pounds.

No. 12.—*Test of Hohenstein water-tube marine boiler, November 18, 1901.*

[Six hours' duration with forced draft.]

Time.	Steam pressure by gauge.	Temperature of feed water.	Calorimeter.			Air pressures in inches of water.					
			Higher temperature.	Lower temperature.	Quality of steam.	Fireroom.	Ashpit.	Furnace.	Combustion chamber.	Tube chamber.	Base of stack.
	Lbs.	° *F.*	° *F.*	° *F.*							
9 a. m.....	275	104	402	303	0.983	1	0.95	0.80	0.75	0.52	—0.55
9.15 a. m..	275	120	402	302	.982½	.4	.50	.40	.40	.30	— .50
9.30 a. m..	275	118	402	306	.984½	1	.95	.80	.67	.55	— .55
9.45 a. m..	275	132	402	301	.981½	1	.95	.80	.70	.50	— .55
10 a. m....	275	112	402	302	.982½	1	.95	.80	.70	.52	— .55
10.15 a. m.	275	131	402	297	.972½	1	.99	.80	.70	.52	— .55
10.30 a. m.	275	124	402	304	.983½	1	.99	.85	.70	.52	— .55
10.45 a. m.	275	113	402	306	.984½	1	.99	.85	.70	.52	— .55
11 a. m....	275	126	402	306	.984½	1	1	.87	.72	.52	— .55
11.15 a. m.	275	117	402	306	.984½	1	.99	.80	.72	.52	— .55
11.30 a. m.	275	120	402	306	.984½	1	1	.80	.70	.52	— .55
11.45 a. m.	275	117	402	307	.985	1	1	.80	.70	.52	— .55
12 m......	275	124	402	307	.985	1	1	.80	.70	.52	— .55
12.15 p. m.	275	108	402	306	.984½	1	1	.80	.70	.52	— .55
12.30 p. m.	275	124	402	304	.983½	1	1	.80	.70	.52	— .55
12.45 p. m.	275	124	402	302	.982½	1	1	.80	.70	.52	— .55
1 p. m.....	275	119	402	302	.982½	1	1	.80	.70	.52	— .55
1.15 p. m..	275	112	401	306	.985	1	1	.80	.70	.52	— .55
1.30 p. m..	275	110	402	306	.984½	1	1	.80	.70	.52	— .55
1.45 p. m..	275	122	402	302	.982½	1	1	.80	.70	.52	— .55
2 p. m.....	275	113	402	305	.984	1	1	.80	.68	.52	— .55
2.15 p. m..	275	110	402	305	.984	1	1	.80	.68	.52	— .55
2.30 p. m..	275	126	402	302	.982½	1	1	.80	.68	.52	— .55
2.45 p. m..	275	135	402	304	.983½	1	1	.80	.68	.52	— .55
3 p. m.....	275	134	402	303	.983	1	1	.80	.68	.52	— .55
Average...	275	119.7	.....	.....	.983	.99	.97	.79	.69	.51	— .55

State of weather, gray and overcast.
Barometer at noon, 30.09 inches.
Kind of fuel, Pocahontas coal, hand picked and screened.
Wood burned in starting fires, 350 pounds.
Coal burned in starting fires, 2,762.

No. 12.—*Test of Hohenstein water-tube marine boiler, November 18, 1901.*

[Six hours' duration with forced draft.]

Time.	Height of water in gauge glass.	Temperature.			Flue gases.		Coal.		Water.	
		Outside air.	Air in fireroom.	Gases at base of stack.	CO₂.	Dry air per pound carbon.	Fired per hour.	Total weight fired.	Fed per hour.	Total weight fed
	Ins.	° *F.*	° *F.*	° *F.*	*Per ct.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*
9 a. m	2¾	50	92							
9.15 a. m	2½		92	502	7.4	14.9				
9.30 a. m	2¾		102							
9.45 a. m	2¼		104	605	8	14.5				
10 a. m	3	51	100				1,232	1,232	11,100	11,100
10.15 a. m	2½		98	590	7.2	14.6				
10.30 a. m	2½		105							
10.45 a. m	2⅛		107	590	6.8	14.9				
11 a. m	2½	52	108				1,383	2,615	10,625	21,725
11.15 a. m	2½		109	590	7.7	14.4				
11.30 a. m	2½		109							
11.45 a. m	2½		106	590	8	15				
12 m	2½	53	106				1,533	4,148	12,054	33,779
12.15 p. m	2½		109	580	6.4	13.9				
12.30 p. m	2½		107							
12.45 p. m	2¾		108	570	6.1	14.1				
1 p. m	2¾	53	110				1,580	5,728	13,397	47,176
1.15 p. m	2		108	590	8.2	14.5				
1.30 p. m	1¾		108							
1.45 p. m	2¼		107	565	6.1	16.3				
2 p. m	4¾	53	102				1,430	7,158	12,701	59,877
2.15 p. m	3½		106	600	7.4	14.8				
2.30 p. m	2¾		106							
2.45 p. m	2		106	575	6.5	14.4				
3 p. m	2¾	53	104				1,230	8,388	10,396	70,273
Average		52	105	580	7.15	14.7	1,398		11,712	

Ashes before beginning test, 526 pounds.
Ashes during test, 837 pounds.
Refuse, including sweepings from tubes and baffles, 562 pounds.
Per cent of moisture in coal by weighing and drying sample, 1.59.
Fired every 7 minutes. Raked after each second firing. No slicing. Very little smoke. No flaming in stack. 9.15 a. m., temporary loss of air pressure due to window blowing out of fireroom.
Total weight of coal fired, 8,388 pounds.
Total weight of water fed, 70,273 pounds.

No. 13.—*Test of Hohenstein water-tube marine boiler, November 27, 1901.*

[Four hours' duration with forced draft.]

Time.	Steam pressure by gauge.	Temperature of feed water.	Calorimeter.			Air pressures in inches of water.					
			Higher temperature.	Lower temperature.	Quality of steam.	Fireroom.	Ash pit.	Furnace.	Combustion chamber.	Tube chamber.	Base of stack.
	Lbs.	° *F.*	° *F.*	° *F.*							
1.15 p. m..	275	100	401	296	0.979	2.1	2	1.90	1.2	0.90	—0.60
1.30 p. m..	275	110	401	296	.979	2.1	2	1.60	1.2	.90	— .75
1.45 p. m..	275	96	401	295	.979	2.1	2	1.65	1.2	.90	— .75
2 p. m	275	82	401	297	.980	2.1	2	1.65	1.2	.90	— .80
2.15 p. m..	275	90	401	296	.979	2.1	2	1.50	1.2	.90	— .80
2.30 p. m..	275	88	401	296	.979	2.1	2	1.62	1.2	.90	— .75
2.45 p. m..	275	90	401	293	.977	2.1	2	1.60	1.2	.85	— .75
3 p. m	275	90	401	294	.978	2.1	2	1.45	1.2	.80	— .75
3.15 p. m..	275	88	402	294	.978	2.1	2	1.57	1.2	.85	— .80
3.30 p. m..	275	92	401	296	.979	2.1	2	1.50	1.1	.80	— .75
3.45 p. m..	275	88	401	296	.979	2.1	2	1.40	1.1	.80	— .75
4 p. m	275	90	401	296	.980	2.1	2	1.45	1.1	.82	— .80
4.15 p. m..	275	94	401	291	.977	2.1	2	1.60	1.2	.90	— .80
4.30 p. m..	275	86	402	293	.977	2.1	2	1.57	1.2	.90	— .80
4.45 p. m..	275	88	402	291	.976	2.1	2	1.62	1.2	.85	— .80
5 p. m	275	90	401	295	.979	2.1	2	1.60	1.2	.85	— .80
5.15 p. m..	275	90	401	295	.979	2.1	2	1.60	1.2	.80	— .80
Average...	275	91.4	.....	.....	.979	2.1	2	1.58	1.18	.86	— .767

State of weather, thin clouds.
Barometer at noon, 30.23 inches.
Kind of fuel, Pocahontas coal, hand picked and screened.
Wood burned in starting fires, 310 pounds.
Coal burned in starting fires, 2,762 pounds.
Ashes before beginning test, 267 pounds.

No. 13.—*Test of Hohenstein water-tube marine boiler, November 27, 1901.*

[Four hours' duration with forced draft.]

Time.	Height of water in gauge glass.	Temperature.			Flue gases.		Coal.		Water.	
		Outside air.	Air in fireroom.	Gases at base of stack.	CO₂.	Dry air per pound carbon.	Fired per hour.	Total weight fired.	Fed per hour.	Total weight fed.
	Ins.	° *F.*	° *F.*	° *F.*	*P. ct.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*
1.15 p. m	2¾	40	80	......	......	......	......	......	......	......
1.30 p. m	1¾	......	83	700	9	13.5	......	......	......	......
1.45 p. m	2¼	......	85	......	......	......	......	......	......	......
2 p. m	2¾	......	86	705	9	14.4	......	......	......	......
2.15 p. m	2½	41	86	......	......	......	2,663	2,663	21,133	21,133
2.30 p. m	2¼	......	87	685	7.7	13.8	......	......	......	......
2.45 p. m	3	......	87	......	......	......	......	......	......	......
3 p. m	2¾	......	86	680	7.4	13.8	......	......	......	......
3.15 p. m	2½	40	90	......	......	......	2,911	5,574	22,436	43,569
3.30 p. m	2½	......	88	740	9.4	13.4	......	......	......	......
3.45 p. m	2½	......	88	......	......	......	......	......	......	......
4 p. m	2¼	......	90	745	9.3	12.8	......	......	......	......
4.15 p. m	2½	40	88	......	......	......	2,662	8,236	22,090	65,659
4.30 p. m	1½	......	86	700	8.1	13.2	......	......	......	......
4.45 p. m	3¾	......	86	......	......	......	......	......	......	......
5 p. m	2	......	84	780	9.2	13.3	......	......	......	......
5.15 p. m	2¾	40	84	......	......	......	2,458	10,694	20,535	86,194
Average	......	40.2	86	717	8.64	13.5	2,674	......	21,549	......

Ashes during test, 460 pounds.

Refuse, including sweepings from tubes and baffles, 936 pounds.

Per cent of moisture in coal, by weighing and drying sample, 1.

Fired every 5 minutes. Raked after each second firing. No fires in stack. Very little smoke. Average by Ringelmann charts, ¼. Boiler casing red hot in places opposite the combustion chamber. The uptake is about 50 per cent larger than in all previous tests.

Total weight of coal fired, 10,694 pounds.

Total weight of water fed, 86,194 pounds.

No. 14.—*Test of Hohenstein water-tube marine boiler, December 16, 1901.*

[Six hours' duration with forced draft.]

Time.	Steam pressure by gauge.	Temperature of feed water.	Calorimeter.			Air pressures in inches of water.					
			Higher temperature.	Lower temperature.	Quality of steam.	Ash pit.	Furnace.	Combustion chamber.	Tube chamber.	Above tubes, below drums.	Base of stack.
	Lbs.	° *F.*	° *F.*	° *F.*							
10.30 a. m..	275	124	400	295	0.979	1	0.70	0.40	0.10	—0.20	—0.50
10.45 a. m..	275	104	400	292	.977	1	.60	.40	.10	— .20	— .50
11 a. m....	275	104	400	290	.976	1	.55	.35	.08	— .20	— .55
11.15 a. m..	275	100	400	294	.979	1	.70	.40	.06	— .20	— .60
11.30 a. m..	275	95	401	295	.979	1	.70	.35	.10	— .20	— .60
11.45 a. m..	275	100	401	293	.978	1	.60	.30	.08	— .20	— .60
12 m......	275	102	401	293	.978	1	.35	.30	.02	— .20	— .60
12.15 p. m.	275	104	401	292	.977	1	.50	.30	.03	— .20	— .60
12.30 p. m.	275	110	402	299	.981	1	.40	.25	.03	— .20	— .60
12.45 p. m.	275	105	402	298	.980	1	.65	.30	.06	— .20	— .60
1 p. m.....	275	110	401	292	.977	1	.55	.30	.06	— .20	— .60
1.15 p. m..	275	112	401	300	.982	1	.50	.25	.05	— .20	— .60
1.30 p. m..	275	105	401	298	.981	1	.55	.25	.03	— .20	— .60
1.45 p. m..	275	106	402	300	.981	1	.55	.25	.08	— .20	— .60
2 p. m.....	275	102	402	304	.984	1	.55	.30	.08	— .20	— .60
2.15 p. m..	275	104	402	297	.980	1	.55	.28	.05	— .20	— .60
2.30 p. m..	275	100	402	296	.979	1	.65	.32	.08	— .20	— .60
2.45 p. m..	275	102	402	295	.979	1	.55	.40	.08	— .20	— .60
3 p. m.....	275	108	402	296	.979	1	.55	.32	.05	— .20	— .60
3.15 p. m..	275	104	402	296	.979	1	.55	.32	.05	— .20	— .60
3.30 p. m..	275	102	402	295	.979	1	.55	.35	.05	— .20	— .60
3.45 p. m..	275	107	402	298	.980	1	.60	.35	.05	— .20	— .60
4 p. m.....	275	102	402	294	.978	1	.60	.35	.05	— .20	— .60
4.15 p. m..	275	107	402	294	.978	1	.55	.30	.03	— .20	— .60
4.30 p. m..	275	96	402	294	.978	1	.60	.35	.06	— .20	— .60
Average...	275	104.6	.....	.....	.980	1	.57	.32	.06	— .20	— .59

State of weather, smoky, with thin clouds.
Barometer at noon, 30.13 inches.
Revolutions of blower, 243 per minute.
Kind of fuel, Pocahontas coal, hand-picked and screened.
Wood burned in starting fires, 350 pounds.
Coal burned in starting fires, 3,256 pounds.
Ashes before beginning test, 271 pounds.
Ashes during test, 714 pounds.
Refuse, including sweepings from tubes and baffles, 923 pounds.
Per cent of moisture in coal, by chemical analysis, 0.73.

No. 14.—*Test of Howenstein water-tube marine boiler, December 16, 1901.*

[Six hours' duration with forced draft.]

Time.	Height of water in gauge glass.	Temperature.			Flue gases, CO_2.	Coal.		Water.	
		Outside air.	Air in fireroom.	Gases at base of stack.		Fired per hour.	Total weight fired.	Fed per hour.	Total weight fed.
	Ins.	° *F.*	° *F.*	° *F.*	*Per cent.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*
10.30 a. m.	4	29	74						
10.45 a. m.	3		70	605	7.2				
11 a. m.	2		70						
11.15 a. m.	2¼		70	725	9.4				
11.30 a. m.	3	32	76			2,364	2,364	18,756	18,756
11.45 a. m.	2¼		76	600	6.5				
12 m.	2½		76						
12.15 p. m.	2¼		70	695	7.3				
12.30 p. m.	2¼	33	76			2,557	4,921	17,721	36,477
12.45 p. m.	3¼		76	740	8.5				
1 p. m.	2½		78						
1.15 p. m.	3½		80	910	9				
1.30 p. m.	2½	34	80			2,468	7,389	18,055	54,532
1.45 p. m.	3½		79	975	9.2				
2 p. m.	2½		80						
2.15 p. m.	2½		80	765	7.8				
2.30 p. m.	2¼	33	80			2,270	9,659	17,820	72,352
2.45 p. m.	2¼		76	810	8.5				
3 p. m.	2½		80						
3.15 p. m.	2		80	785	8.5				
3.30 p. m.	2½	33	80			2,367	12,026	18,037	90,389
3.45 p. m.	2		79	830	7.8				
4 p. m.	3		80						
4.15 p. m.	2¼		79	740	7.7				
4.30 p. m.	4	32	80			2,033	14,029	18,374	108,763
Average		32.3	77	766	8.1	2,038		18,127	

Start delayed by the freezing of the feed pipe. Fired every 5 minutes. Raked after each firing. Clinker in left furnace at end of second hour. The firing was even and good, except when the fires were allowed to get too thick. The usual thickness was 8 inches to 10 inches, but at one time 12 inches were carried when flames appeared in the base of the stack. The flames would last but a few seconds, during which the stack temperature would go up to 1050° F. Average smoke by Ringelmann charts, 1¼. The uptake area is about twice what it was in the first twelve tests.

Total weight of coal fired, 14,029 pounds.

Total weight of water fed, 108,763 pounds.

No. 15.—*Test of Hohenstein water-tube marine boiler, December 18, 1901.*

[Eight hours' duration, with natural draft.]

Time.	Steam pressure by gauge.	Temperature of feed water.	Calorimeter.			Air pressures in inches of water.				
			Higher temperature.	Lower temperature.	Quality of steam.	Furnace.	Combustion chamber.	Tube chamber.	Abovetubes, below drums.	Base of stack.
	Lbs.	° *F.*	° *F.*	° *F.*						
8.30 a. m...	275	116	402	302	0.983	−0.20	−0.20	−0.25	−0.40	−0.50
8.45 a. m...	275	126	404	304	.983	− .20	− .20	.25	− .35	− .50
9 a. m	275	122	404	304	.983	.20	− .20	− .25	− .35	− .50
9.15 a. m...	275	125	404	303	.982	.20	− .20	.25	− .35	.50
9.30 a. m...	275	119	404	305	.983	− .20	− .20	− .25	− .35	− .50
9.45 a. m...	275	130	403	306	.984	.20	− .20	.25	− .35	.50
10 a. m	275	121	404	305	.983	− .20	− .20	− .25	− .35	− .50
10.15 a. m..	275	123	404	306	.984	− .20	− .20	− .25	− .35	− .50
10.30 a. m..	275	117	404	306	.984	− .20	.20	− .25	− .35	− .50
10.45 a. m..	275	134	404	306	.984	− .20	− .20	− .25	− .37	− .52
11 a. m	275	128	404	307	.985	− .20	− .20	.25	− .40	.52
11.15 a. m..	275	126	404	307	.985	.20	− .20	− .25	− .40	− .50
11.30 a. m..	275	110	404	308	.985	− .20	− .20	.25	− .40	− .50
11.45 a. m..	275	130	404	306	.984	.20	.20	− .25	− .37	− .52
12 m	275	119	404	308	.985	− .20	− .20	− .25	− .37	− .50
12.15 p. m..	275	120	404	308	.985	.20	− .20	− .25	− .37	− .50
12.30 p. m..	275	140	404	308	.986	− .20	− .20	− .25	− .37	− .50
12.45 p. m..	275	126	404	308	.985	− .20	− .20	.25	− .40	− .50
1 p. m	275	130	404	309	.986	− .20	− .20	− .25	− .37	.50
1.15 p. m...	275	122	404	309	.986	− .20	.20	.25	− .38	− .50
1.30 p. m...	275	118	404	310	.987	− .20	.20	− .25	− .40	− .50
1.45 p. m...	275	130	404	309	.986	.20	− .20	.25	− .37	− .50
2 p. m	275	122	404	309	.986	.20	− .20	− .25	− .37	− .50
2.15 p. m...	275	135	402	309	.986	− .20	− .20	− .25	− .40	− .50
2.30 p. m...	275	122	404	310	.987	− .20	− .20	− .25	.40	− .50
2.45 p. m...	275	122	404	306	.984	− .20	− .20	− .25	− .35	− .55
3 p. m	275	126	404	310	.986	.20	.20	− .25	− .40	− .50
3.15 p. m...	275	135	404	309	.986	− .20	− .20	.25	− .40	− .55
3.30 p. m...	275	126	404	309	.986	− .20	− .20	− .25	− .40	− .55
3.45 p. m...	275	129	403	308	.985	− .20	− .20	− .25	− .40	− .55
4 p. m	275	125	404	309	.986	− .20	− .20	− .25	− .40	− .55
4.15 p. m...	275	133	404	306	.984	− .20	.20	− .25	− .40	− .55
4.30 p. m...	275	119	404	306	.984	− .20	− .20	− .25	− .40	− .55
Average ...	275	125	.....	......	.985	.20	− .20	.25	.38	− .51

State of weather, smoky, with thin clouds.
Barometer at noon, 30.01 inches.
Kind of fuel, Pocahontas coal, hand picked and screened.
Wood burned in starting fires, 360 pounds.
Coal burned in starting fires, 2,440 pounds.
Ashes before beginning test, 235 pounds.

No. 15.—*Test of Hohenstein water-tube marine boiler, December 18, 1901.*

[Eight hours' duration, with natural draft.]

Time.	Height of water in gauge glass.	Temperature.			Flue gases.			Dry air per pound carbon.	Coal fired per hour.	Water fed per hour.
		Outside air.	Air in fire room.	Gases at base of stack.	CO_2.	O.	CO.			
	Ins.	° *F.*	° *F.*	° *F.*	*P. ct.*	*P. ct.*	*P. ct.*	*Lbs.*	*Lbs.*	*Lbs.*
8.30 a. m.	3	22	73	......	......	......	......	......	......	......
8.45 a. m.	2½	......	74	525	5.8	......	......	......	......	......
9 a. m.	2½	......	67	......	......	......	......	......	......	......
9.15 a. m.	2½	......	71	570	7.2	......	......	......	......	......
9.30 a. m.	3	25	74	......	......	......	......	......	1,034	10,466
9.45 a. m.	2¾	......	77	565	8.2	......	......	......	......	......
10 a. m.	2½	......	82	......	......	......	......	......	......	......
10.15 a. m.	2¾	......	79	570	7.5	......	......	......	......	......
10.30 a. m.	3	25	81	......	......	......	......	......	1,134	10,436
10.45 a. m.	3	......	82	555	7	......	......	......	......	......
11 a. m.	2¾	......	82	......	......	......	......	......	......	......
11.15 a. m.	2¾	......	83	555	6.6	......	......	......	......	......
11.30 a. m.	3	26	87	......	......	......	......	......	1,186	9,908
11.45 a. m.	2½	......	88	555	6.8	......	......	......	......	......
12 m.	3	......	92	......	......	......	......	......	......	......
12.15 p. m.	2¾	......	90	565	8.5	11.5	0	27.1	......	......
12.30 p. m.	3	26	89	......	......	......	......	......	1,183	10,083
12.45 p. m.	2½	......	86	570	8.1	10.9	0	27.1	......	......
1 p. m.	3	......	89	......	......	......	......	......	......	......
1.15 p. m.	3	......	89	595	9.4	10.4	.2	23.9	......	......
1.30 p. m.	3	27	90	......	......	......	......	......	1,183	10,525
1.45 p. m.	2¾	......	92	565	8.2	10.6	.1	26.2	......	......
2 p. m.	2¾	......	95	......	......	......	......	......	......	......
2.15 p. m.	3	......	99	585	8.4	11.4	0	27.3	......	......
2.30 p. m.	4¼	28	102	......	......	......	......	......	1,184	10,150
2.45 p. m.	2¾	......	99	580	8.9	11.1	.2	25.5	......	......
3 p. m.	3	......	96	......	......	......	......	......	......	......
3.15 p. m.	3	......	96	585	7.3	12.9	0	32	......	......
3.30 p. m.	3	26	97	......	......	......	......	......	1,183	9,407
3.45 p. m.	3	......	92	585	8.5	11.2	.2	26.3	......	......
4 p. m.	3	......	95	......	......	......	......	......	......	......
4.15 p. m.	2¾	......	90	570	7.2	12.8	.1	31.7	......	......
4.30 p. m.	3	26	92	......	......	......	......	......	1,194	10,043
Average		26	87	568	7.9	11.4	.9	27.5	1,148	10,127

Ashes during test, 702 pounds.
Refuse, including sweepings from tubes and baffles, 576 pounds.
Per cent of moisture in coal, by chemical analysis, 0.73.
Fired every 10 minutes. Raked after each firing. Practically no smoke.
Total weight of coal fired, 9,181 pounds.
Total weight of water fed, 81,018 pounds.

No. 16.—*Test of Hohenstein water-tube marine boiler, December 21, 1901.*

[Four hours' duration with forced draft.]

Time.	Steam pressure by gauge.	Temperature of feed water.	Calorimeter.			Air pressures, in inches of water.					
			Higher temperature.	Lower temperature.	Quality of steam.	Ash pit.	Furnace.	Combustion chamber.	Tube chamber.	Above tubes, below drums.	Base of stack.
	Lbs.	° *F.*	° *F.*	° *F.*							
9.45 a. m..	275	112	402	286	0.973	2	1.55	1.1	0.30	−0.05	−0.50
10 a. m....	275	111	402	288	.975	2	1.60	1	.30	− .07	− .60
10.15 a. m.	275	101	402	289	.975	2	1.40	.9	.30	− .07	− .60
10.30 a. m.	275	90	402	291	.976	2	1.35	1	.30	− .07	− .60
10.45 a. m.	275	91	402	292	.977	2	1.20	.9	.27	− .07	− .60
11 a. m....	275	93	402	294	.978	2	1.30	.95	.27	− .05	− .65
11.15 a. m.	275	99	402	294	.978	2	1.40	.9	.25	− .05	− .65
11.30 a. m.	275	96	402	291	.976	2	1.35	.85	.25	− .07	− .70
11.45 a. m.	275	96	402	291	.976	2	1.45	.95	.23	− .07	− .65
12 m......	275	96	402	292	.977	2	1.45	.9	.20	− .05	− .70
12.15 p. m.	275	100	402	295	.978	2	1.40	.9	.20	− .05	− .70
12.30 p. m.	275	98	402	296	.979	2	1.25	.95	.19	− .10	− .67
12.45 p. m.	275	100	402	294	.978	2	1.45	.97	.19	− .07	− .65
1 p. m	275	96	402	292	.977	2	1.35	.85	.19	− .10	− .65
1.15 p. m..	275	98	402	292	.977	2	1.40	.9	.20	− .10	− .70
1.30 p. m..	275	96	402	294	.978	2	1.35	.9	.20	− .10	− .70
1.45 p. m..	275	99	402	294	.978	2	1.50	.9	.20	− .10	− .65
Average...	275	98.4	.....	.....	.978	2	1.40	.93	.24	− .07	− .64

State of weather, smoky, no clouds.
Barometer at noon, 30.28 inches.
Revolutions of blower, 332 per minute.
Kind of fuel, Pocahontas coal, hand picked and screened.
Wood burned in starting fires, 450 pounds.
Coal burned in starting fires, 3,130 pounds.

No. 16.—*Test of Hohenstein water-tube marine boiler, December 21, 1901.*

[Four hours' duration with forced draft.]

Time.	Height of water in gauge glass.	Temperature.			Flue gases.				Coal fired per hour.	Water fed per hour.
		Outside air.	Air in fireroom.	Gases at base of stack.	CO_2.	O.	CO.	Dry air per pound carbon.		
	Ins.	° *F.*	° *F.*	° *F.*	*P. ct.*	*P. ct.*	*P. ct.*	*Lbs.*	*Lbs.*	*Lbs.*
9.45 a. m...	3½	18	60	......	......	......	......	......	......	......
10 a. m	2½	......	60	680	7.8	11.2	3.7	20.9	......	......
10.15 a. m..	2	......	60	......	......	......	......	......	......	......
10.30 a. m..	3	......	62	730	9	10.4	.3	24.2	......	......
10.45 a. m..	3	20	62	......	......	......	......	......	3,353	22,145
11 a. m	2½	......	63	840	9.1	9.4	1.4	21.1	......	......
11.15 a. m..	2	......	64	......	......	......	......	......	......	......
11.30 a. m..	1¾	......	65	785	8	10	1.6	22.6	......	......
11.45 a. m..	3	24	64	......	......	......	......	......	3,161	23,401
12 m	2¾	......	65	900	8.7	9.2	.5	22.7	......	......
12.15 p. m..	2½	......	68	......	......	......	......	......	......	......
12.30 p. m..	2¼	......	68	780	9	9.7	.9	22.3	......	......
12.45 p. m..	2¼	24	66	......	......	......	......	......	3,157	23,157
1 p. m	2½	......	68	815	9.4	10	.6	22.7	......	......
1.15 p. m...	2½	......	68	......	......	......	......	......	......	......
1.30 p. m...	2	......	66	880	10.3	9.2	.2	21.6	......	......
1.45 p. m...	3½	26	67	......	......	......	......	......	2,941	23,720
Average ...	......	22	64	800	8.9	9.0	1.1	22.3	3,153	23,106

Ashes before beginning test, 105 pounds.
Ashes during test, 646 pounds.
Refuse, including sweepings from tubes and baffles, 895 pounds.
Per cent of moisture in coal by chemical analysis, 0.73.
Fired every 5 minutes. Raked after each firing. Occasional flames in stack. Very little smoke.
Average by Ringelmann charts, 1.
Total weight of coal fired, 12,612 pounds.
Total weight of water fed, 92,423 pounds.

No. 17.—*Test of Hohenstein water-tube marine boiler, January 11, 1902.*

[Three hours' duration with forced draft.]

Time.	Steam pressure by gauge.	Temperature of feed water.	Calorimeter.			Air pressures, in inches of water.					
			Higher temperature.	Lower temperature.	Quality of steam.	Ash pit.	Furnace.	Combustion chamber.	Tube chamber.	Above tubes, below drums.	Base of stack.
	Lbs.	° *F.*	° *F.*	° *F.*							
10 a. m....	275	89	400	280	0.970	3	2.20	1.30	0.75	0.10	−0.55
10.15 a. m .	275	90	400	283	.972	3	2.10	1.30	.72	.10	− .55
10.30 a. m .	275	80	400	284	.973	3	2.25	1.50	.80	.10	− .55
10.45 a. m .	275	80	400	283	.972	3	2.20	1.60	.80	.10	− .55
11 a. m....	275	94	402	284	.972	3	1.95	1.40	.80	.10	− .55
11.15 a. m .	275	93	402	286	.973	3	2.20	1.50	.85	.10	− .55
11.30 a. m .	275	85	402	287	.974	3	2.10	1.40	.85	.10	− .55
11.45 a. m .	275	90	401	288	.975	3	2.20	1.30	.80	.10	− .55
12 m	275	90	400	288	.975	3	2.35	1.45	.85	.10	.55
12.15 p. m .	275	85	401	288	.975	3	2.20	1.50	.82	.10	− .55
12.30 p. m.	275	84	402	292	.977	3	2	1.50	.85	.10	− .55
12.45 p. m.	275	94	400	289	.976	3	2.20	1.45	.90	.10	− .55
1 p. m.....	275	89	401	289	.975	3	2.20	1.45	.90	.10	− .55
Average...	275	88	......	......	.974	3	2.16	1.44	.82	.10	− .55

State of weather, dark, fog, and smoke.
Barometer at noon, 29.58 inches.
Revolutions of blower, 423 per minute.
Kind of fuel, Pocahontas coal, hand-picked and screened.
Wood burned in starting fires, 350 pounds.
Coal burned in starting fires, 3,554 pounds.
Ashes before beginning test, 151 pounds.

No. 17.—*Test of Hohenstein water-tube marine boiler, January 11, 1902.*

[Three hours' duration with forced draft.]

Time.	Height of water in gauge glass.	Temperature.			Flue gases.				Coal fired per hour.	Water fed per hour.
		Outside air.	Air in fireroom.	Gases at base of stack.	CO$_2$.	O.	CO.	Dry air per pound carbon.		
	Ins.	°*F.*	°*F.*	°*F.*	*P. ct.*	*P. ct.*	*P. ct.*	*Lbs.*	*Lbs.*	*Lbs.*
10 a. m	2¼	34	75	......	......	......	......	......	....	......
10.15 a. m..	2½	......	78	900	9	9.4	1	21.8	....	......
10.30 a. m..	2	......	77	......	......	......	......	......	....	......
10.45 a. m..	3	......	79	900	9.6	8.8	.6	21.2	....	......
11 a. m	2	37	77	......	......	......	......	......	3,749	26,430
11.15 a. m..	1½	......	76	910	10	9.2	.6	21.2	....	......
11.30 a. m..	2	......	76	......	......	......	......	......	....	......
11.45 a. m..	1¾	......	77	850	9.7	9.5	.4	22.2	....	......
12 m	2	36	76	......	......	......	......	......	3,552	26,037
12.15 p. m..	2	......	76	1,200	10.4	8.1	.6	19.7	....	......
12.30 p. m..	2½	......	76	......	......	......	......	......	....	......
12.45 p. m..	2	......	76	900	9.8	9.5	.3	22.2	....	......
1 p. m	2	34	76	......	......	......	......	......	3,561	25,390
Average		35	76.5	943	9.7	9.1	.6	21.4	3,621	25,952

Ashes during test, 254 pounds.

Refuse, including sweepings from tubes and baffles, 1,355 pounds.

Per cent of moisture in coal by chemical analysis, 0.73.

Fired every 3 minutes. Raked after each firing. Occasional flames in stack. Practically no smoke.

At 1 p. m. the draft pressure was increased to 4 inches, and the intention was to run at that pressure until the supply of coal was exhausted, which would have taken about 45 minutes; but at 1.02 p. m. the test was brought to a sudden stop by the failure of the feed water.

Total weight of coal fired, 10,862 pounds.

Total weight of water fed, 77,857 pounds.

Summary of seventeen tests of Hohenstein marine water-tube boiler, burning coal.

Number of trial.	Date of trial.	Duration of trial (hours).	Kind of fuel (P., Pocahontas coal; N. R., New River coal; r. m., run of mine; h. p. s., hand picked and screened).	State of weather.	Height of barometer at noon.
1	2	3	4	5	6
	1901.				
1.....	Apr. 23	8	P., r. m...........	Clear..	30.02
2.....	Apr. 26	6	.....do............	Dull and overcast........................	30.12
3.....	May 8	4	.....do............	.....do..	29.86
4.....	May 29	8	.....do............	Squally...	29.70
5.....	June 5	6	.....do............	Bright and sunshiny......................	30.08
6.....	June 8	3½	.....do............	.....do..	29.95
7.....	Oct. 21	8	N. R., r. m........	Clear..	30.34
8.....	Oct. 23	6	.....do............	Cloudy...	29.95
9.....	Oct. 26	4	.....do............	Smoky..	30.25
10.....	Nov. 6	8	P., h. p. s.........	Clear and damp.............................	30.20
11.....	Nov. 9	8	.....do............	Cloudy, occasional sun..................	30.18
12.....	Nov. 18	6	.....do............	Gray and overcast.........................	30.09
13.....	Nov. 27	4	.....do............	Thin clouds..................................	30.23
14.....	Dec. 16	6	.....do............	Smoky, with thin clouds.................	30.13
15.....	Dec. 18	8	.....do............	.....do..	30.01
16.....	Dec. 21	4	.....do............	Smoky, no clouds..........................	30.28
	1902.				
17.....	Jan. 11	3	.....do............	Dark, fog, and smoke.....................	29.58

Number of trial.	Approximate fireroom air pressure.	Average temperature.					Fuel.					
		External air (° F.).	Air in fireroom (° F.).	Chimney gases (° F.).	Feed water entering boiler (° F.).	Steam at gauge pressure (7) from steam tables (° F.).	Weight of wood used in starting fires (pounds).	Weight of coal used in starting fires (pounds).	Weight of coal used during test (pounds).	Total weight of fuel used (pounds), (21) + (22) + (23).	Weight of ashes before beginning test (pounds).	Weight of ashes during test (pounds).
1	8	16	17	18	19	20	21	22	23	24	25	26
1.....	0	57.2	93.8	594	144	410.4	350	2,400	9,720	12,470	260	377
2.....	1	70.3	117.8	751	145.4	413.3	800	2,000	10,445	12,745	160	575
3.....	2	72.8	121.7	1,089	145.8	413.7	390	2,500	10,569	13,459	195	459
4.....	0	64.4	114	688	137	412.7	340	2,000	8,633	10,973	175	226
5.....	1	84.1	139.5	712	129.3	413.1	360	2,200	10,695	13,255	200	1,038
6.....	2	74.8	127.3	1,105	116.5	412.5	(?)	(?)	8,461	8,461	(?)	591
7.....	0	71.3	144	563	131.8	413.6	360	2,000	8,056	10,416	198	485
8.....	1	74.3	124	654	126.1	413.6	250	1,910	9,698	11,858	161	365
9.....	2	68	106.5	688	111.8	413.6	361	2,200	9,000	11,561	152	391
10.....	0	62.7	125	548	125.9	413.6	350	2,792	8,299	11,441	225	214
11.....	0	55.1	125.4	521	122.3	413.6	350	1,435	7,436	9,221	303	584
12.....	1	52	105	580	119.7	413.6	350	2,762	8,388	11,500	526	837
13.....	2	40.2	86	717	91.4	413.6	310	2,762	10,694	13,766	267	460
14.....	1	32.3	77	766	104.6	413.6	350	3,256	14,029	17,635	271	714
15.....	0	26	87	568	125	413.6	360	2,440	9,181	11,981	235	702
16.....	2	22	64	800	98.4	413.6	450	3,130	12,612	16,192	105	646
17.....	3	35.4	76.5	943	88	413.6	350	3,554	10,862	14,766	151	254

Summary of seventeen tests of Hohenstein marine water-tube boiler, burning coal.

Average pressures.								
Steam pressure by gauge; corrected for water level, pounds per square inch.	Draft pressures, in inches of water.							Revolutions of blower per minute.
	Fireroom.	Ash pit.	Furnace.	Combustion chamber.	Tube chamber.	Above tubes and below drums.	Base of stack.	
7	8	9	10	11	12	13	14	15
263.9	0.0	−0.05	....	....	....	....	−0.52	0
272.9	1.08	1.02	....	....	....	....	− .65	250
274.6	2.06	2	....	....	....	....	− .84	335
271.3	0.0	− .04	−0.18	−0.20	−0.21	....	− .24	0
272.5	1.06	1.02	.80	.62	....	....	− .41	243
270.5	2.03	2	1.56	1.41	....	....	− .22	375
273.5	0.0	− .05	− .16	− .12	− .22	....	− .50	0
273.5	1.07	1	.81	.72	.52	....	− .46	243
273.5	2.10	2	1.43	1.25	1.08	....	− .98	375
273.5	0.0	− .05	− .15	− .14	− .19	....	− .55	0
273.5	0.0	− .05	− .09	− .09	− .11	....	− .55	0
273.5	.99	.97	.79	.69	.51	....	− .55	240
273.5	2.10	2.00	1.58	1.18	.86	....	− .77	375
273.5	....	1.00	.57	.32	.06	−0.20	− .59	243
273.5	....	0	− .20	− .20	− .25	− .38	− .51	0
273.5	....	2.00	1.41	.93	.24	− .07	− .64	332
273.5	....	3.00	2.16	1.44	.82	.10	− .55	423

Fuel.								Steam.	
Weight of refuse from furnace, tubes, baffles, etc. (pounds).	Total weight of ashes and refuse (pounds), (25)+(26)+(27).	Percentage of ashes and refuse, (28)÷(24)×100.	Weight of ashes and refuse from coal used during test (pounds), (23)×(29)÷100.	Percentage of moisture in coal (*by weighing and drying sample; †by chemical analysis).	Weight of moisture in coal used during test (pounds) (23)×(31)÷100.	Weight of dry coal burned during test (pounds), (23)−(32).	Weight of combustible burned during test (pounds), (33)−(30).	Quality of steam.	Percentage of moisture in steam, 100−100×(35).
27	28	29	30	31	32	33	34	35	36
640	1,277	10.24	995	*0.50	49	9,761	8,676	0.980	2
550	1,285	10.08	1,053	* .50	52	10,393	9,340	.968	3.2
815	1,469	10.91	1,153	* .50	53	10,516	9,363	.989	1.1
549	950	8.66	747	† .79	68	8,565	7,818	.990	1
589	1,777	13.40	1,432	† .79	85	10,610	9,178	.988	1.2
626	1,217	14.87	1,216	† .79	67	8,394	7,178	.990	1
561	1,244	11.95	963	*3.14	253	7,803	840	.986	1.4
528	1,054	8.89	862	*3.14	304	9,394	8,532	.976	2.4
732	1,275	11.03	993	*3.14	283	8,717	7,724	.980	2
526	965	8.44	700	*2.04	169	8,130	7,430	.988	1.2
356	1,243	13.48	1,003	*1.15	85	7,351	6,348	.987	1.3
562	1,925	16.75	1,405	*1.59	134	8,254	6,849	.983	1.7
936	1,663	12.08	1,292	*1	107	10,587	9,295	.979	2.1
923	1,908	10.82	1,518	† .73	102	13,927	12,409	.980	2
576	1,513	12.63	1,160	† .73	67	9,114	7,954	.985	1.5
895	1,646	10.18	1,285	† .73	92	12,520	11,235	.978	2.2
1,355	1,760	11.92	1,295	† .73	79	10,783	9,488	.974	2.6

Summary of seventeen tests of Hohenstein marine boiler, December 21, 1901—Continued.

		Water.				Economic results.			
Number of trial.	Approximate fire-room air pressure.	Total weight of water fed to boiler (pounds), (corrected for inequality of water level and steam pressure at beginning and end of test).	Equivalent weight of water evaporated into dry steam (pounds), (37) × (35).	Factor of evaporation (H—h) ÷ 965.7.	Equivalent weight of water evaporated into dry steam from and at 212° F. (pounds), (38) × (39).	Feed water per pound of coal as fired (pounds) (37) ÷ (23).	Equivalent evaporation from and at 212° F. per pound of coal as fired (pounds), (40) ÷ (23).	Equivalent evaporation from and at 212° F. per pound of dry coal (pounds), (40) ÷ (33).	Equivalent evaporation from and at 212° F. per pound of combustible (pounds), (40) ÷ (34).
1	8	37	38	39	40	41	42	43	44
1.....	0	76,016	74,455	1.134	84,430	7.82	8.69	8.73	9.74
2.....	1	86,673	81,260	1.133	92,060	8.30	8.81	8.86	9.86
3.....	2	79,803	78,700	1.133	89,170	7.55	8.44	8.48	9.52
4.....	0	77,953	77,120	1.142	88,070	9.03	10.20	10.28	11.26
5.....	1	92,458	91,300	1.150	104,740	8.65	9.79	9.87	11.41
6.....	2	60,539	59,800	1.163	69,540	7.15	8.22	8.28	9.69
7.....	0	68,415	67,450	1.147	77,360	8.50	9.60	9.91	11.30
8.....	1	80,747	78,800	1.153	90,950	8.33	9.38	9.68	10.66
9.....	2	71,644	70,200	1.169	82,070	7.96	9.12	9.42	10.63
10.....	0	70,148	69,300	1.154	79,980	8.45	9.64	9.84	10.76
11.....	0	65,430	64,570	1.157	74,710	8.80	10.05	10.16	11.77
12.....	1	70,273	69,070	1.159	80,060	8.38	9.55	9.70	11.69
13.....	2	86,194	84,370	1.189	100,320	8.06	9.38	9.48	10.79
14.....	1	108,763	106,580	1.176	125,350	7.75	8.94	9.00	10.10
15.....	0	81,018	79,790	1.155	92,160	8.82	10.04	10.11	11.59
16.....	2	92,423	90,390	1.182	106,840	7.33	8.47	8.53	9.52
17.....	3	77,857	75,820	1.193	90,450	7.17	8.33	8.39	9.53

		Chimney-gas analysis.					Heat balance or distribution of the heating value of the combustible.			
Number of trial.	Approximate fire-room air pressure.	Carbonic acid, CO_2 (per cent).	Oxygen, O (per cent).	Carbonic oxide, CO (per cent).	Nitrogen, N (per cent by difference).	Pounds of dry gas per pound of carbon [11(56)+8(57)+7(58)+7(59)] ÷ [3(56)+3(58)].	Heat absorbed by the boiler (B.T.U.'s), (44) × 965.7.	Loss due to moisture in coal (B.T.U.'s).	Loss due to the moisture formed by the burning of hydrogen (B.T.U.'s).	Loss due to heat carried away in the dry chimney gases (B.T.U.'s).
1	8	56	57	58	59	60	61	62	63	64
1.....	0	9.85	6.85	1.67	81.63	21.5	9,400	7	486	2,320
2.....	1	9.46	6.50	1.96	82.08	21.7	9,520	7	505	2,970
3.....	2	12.42	4.85	1	81.73	18.7	9,190	8	566	3,930
4.....	0	11.08	4.75	2.19	81.98	18.8	10,870	11	492	2,290
5.....	1	10.35	5.03	2.20	82.42	19.8	11,020	12	487	2,400
6.....	2	13.77	3.73	93	81.57	17.2	9,360	14	564	3,570
7.....	0	9.26	6.48	1.52	82.74	23	10,910	43	555	2,050
8.....	1	8.87	6.94	1.59	82.60	23.6	10,290	44	584	2,650
9.....	2	9.20	6.40	1.70	82.70	23.7	10,260	46	600	2,800
10.....	0	8.89	....	....	....	....	10,390	27	501	....
11.....	0	8	....	....	....	....	11,360	16	496	....
12.....	1	7.15	....	....	....	....	11,290	24	516	....
13.....	2	8.64	....	....	....	....	10,410	15	551	....
14.....	1	8.10	....	....	....	....	9,750	11	565	....
15.....	0	7.90	11.4	.90	79.80	28.1	11,190	11	521	2,740
16.....	2	8.90	9	1.10	81	24.8	9,190	11	577	3,880
17.....	3	9.70	9.1	.60	80.60	23.8	9,200	12	600	4,380

Summary of seventeen tests of Hohenstein marine boiler, December 21, 1901—Continued.

Fuel per hour.						Water per hour.				
Coal as fired per hour (pounds), (23) ÷ (8).	Dry coal per hour (pounds), (33) ÷ ()8.	Combustible per hour (pounds), (34) ÷ (3).	Coal as fired per hour per square foot of grate (pounds), (45) ÷ 50.14.	Dry coal per hour per square foot of grate (pounds), (46) ÷ 50.14.	Combustible per hour per square foot of grate (pounds), (47) ÷ 50.14.	Feed water per hour (pounds), (37) ÷ (3).	Water per hour corrected for quality of steam (pounds), (38) ÷ (3).	Equivalent evaporation from and at 212° F. per hour (pounds), (40) ÷ (3).	Equivalent evaporation from and at 212° F. per hour per square foot of grate (pounds), (53) ÷ 50.14.	Equivalent evaporation from and at 212° F. per hour per square foot of heating surface (pounds), (53) ÷ heating surface.
45	**46**	**47**	**48**	**49**	**50**	**51**	**52**	**53**	**54**	**55**
1,215	1,209	1,085	24.2	24.1	21.6	9,502	9,307	10,554	210	4.85
1,741	1,732	1,557	34.7	34.5	31	14,446	13,543	15,343	306	7.05
2,642	2,629	2,341	52.6	52.4	46.7	19,951	19,675	22,292	445	10.25
1,079	1,071	977	21.5	21.3	19.5	9,744	9,640	11,009	219	5.06
1,782	1,769	1,530	35.5	35.2	30.5	15,410	15,180	17,457	348	8.03
2,417	2,398	2,051	48.2	47.8	40.8	17,297	17,086	19,869	396	9.14
1,007	975	855	20.1	19.4	17	8,552	8,431	9,670	193	4.53
1,616	1,566	1,422	32.2	31.2	28.3	13,458	13,133	15,158	302	7.11
2,250	2,179	1,931	44.8	43.4	38.4	17,911	17,554	20,518	411	9.64
1,037	1,016	929	20.7	20.2	18.5	8,769	8,663	9,998	199	4.69
930	919	794	18.5	18.3	15.8	8,179	8,071	9,339	186	4.38
1,398	1,376	1,142	27.8	27.4	22.7	11,712	11,512	13,343	266	6.26
2,674	2,647	2,324	53.4	52.8	46.2	21,549	21,092	25,080	500	11.77
2,338	2 321	2,068	46.6	46.3	41.2	18,127	17,763	20,892	417	9.81
1,148	1,139	994	22.9	22.7	19.8	10,127	9,974	11,520	229	5.40
3,153	3,130	2,809	62.9	62.4	56	23,106	22,598	26,710	533	12.54
3,621	3,594	3,163	72.2	71.7	63.1	25,952	25,273	30,150	602	14.15

Heat balance or distribution of the heating value of the combustible.									Efficiency.	
Loss due to the incomplete combustion of carbon (B. T.U.'s).	Loss due to unconsumed hydrogen, etc., to heating moisture in air, to radiation, etc. (B.T.U.'s).	Heat value of one pound of combustible calculated from ultimate chemical analysis (B.T.U.'s).	Heat absorbed by boiler (per cent).	Loss due to moisture in coal (per cent).	Loss due to moisture formed by the burning of hydrogen (per cent).	Loss due to heat carried away in the dry chimney gases (per cent).	Loss due to incomplete combustion of carbon (per cent).	Other losses due to radiation, etc. (per cent by difference).	Of boiler (per cent), (61) ÷ (67) ×100.	Of boiler and furnace (per cent), 965.7 (43) ÷ B. T. U.'s per pound of dry coal ×100.
65	**66**	**67**	**68**	**69**	**70**	**71**	**72**	**73**	**74**	**75**
1,325	1,853	15,391	61	0.1	3.2	15.1	8.6	12	61	60
1,571	818	15,391	61.8	.1	3.3	19.3	10.2	5.3	61.8	60.8
682	1,015	15,391	59.7	.1	3.7	25.5	4.4	6.6	59.7	58.2
1,388	73	15,124	71.8	.1	3.3	15.1	9.2	.5	71.8	68.3
1,569	−364	15,124	72.8	.1	3.2	15.9	10.4	−2.4	72.8	65.6
567	1,049	15,124	62	.1	3.7	23.6	3.7	6.9	61.9	55
1,265	861	15,684	69.5	.3	3.5	13.1	8.1	5.5	69.6	64.4
1,362	754	15,684	65.6	.3	3.7	16.9	8.7	4.8	65.6	63
1,398	580	15,684	65.5	.3	3.8	17.8	8.9	3.7	65.4	61.3
....	....	15,475	67.1	....	3.2	....	....	....	67.1	63.3
....	....	15,475	73.4	....	3.2	....	....	....	73.4	65.4
....	....	15,475	72.9	....	3.3	....	....	....	73	62.4
....	....	15,475	67.2	....	3.6	....	....	....	67.2	61
....	....	15,475	63	....	3.7	....	....	....	63	57.9
908	105	15,475	72.2	.1	3.4	17.7	5.9	.7	72.3	65
989	828	15,475	59.4	.1	3.7	25.1	6.4	5.3	59.4	54.9
519	764	15,475	59.4	.1	3.9	28.3	3.4	4.9	59.4	54

INCREASED EVAPORATIVE CAPACITY SHOULD BE DEMANDED OF WATER-TUBE BOILERS OF THE STRAIGHT-TUBE TYPE.

The result of the capacity tests of the experimental boiler conclusively showed that naval administrators will be justified in prescribing that all straight-tube naval boilers should be required to burn at least 40 pounds of coal per square foot of grate per hour under forced draft, and that in order to effect such a rate of combustion the limit of air pressure may be allowed to reach 2½ to 3 inches. By reason of the practical ability to secure increased coal combustion in marine boilers of the water-tube type the maximum I. H. P. now required of each square foot of grate surface should be increased.

The searching power of air when under several inches water pressure was likewise conclusively shown during these experiments, for great difficulty was experienced in preventing leakage through the steel structure. These tests also showed the advisability of ascertaining whether it is possible to maintain 2 inches of forced draft pressure for several continuous hours in all the compartments of a battle ship while securing the capacity and efficiency of evaporation that should accompany such high air pressure. Greater air pressure has been carried in boiler compartments, but careful investigation shows that at such times the fires were so thick that the coal consumption seldom exceeded 40 pounds per square foot of grate. It will be found in practice that the limit to which the entire boiler plant of a war ship can be forced is quite different from results secured when the entire fire-room complement and all the blowers are employed in experimental work upon a few boilers..

THE PROBLEM OF THE WATER-TUBE BOILER.

As the board was originally appointed to determine the value of the Hohenstein boiler for naval purposes, as well as to conduct experiments wherein definite data could be secured relating to the naval-boiler problem, special observation was made as to the endurance of this type of boiler when using both coal and oil.

The boiler problem is of such importance in maritime matters that the solution of the fuel question is intimatly connected with the design of the steam generator.

The following extract from the report of the Engineer in Chief of the Navy, Rear-Admiral George W. Melville, U. S. Navy, for the fiscal year ending June 30, 1902, so succinctly states the importance of the boiler problem in naval warfare that the Liquid Fuel Board incorporates these views as reflecting its general opinions upon the importance of installing an approved type of boiler that will possess both economical efficiency and endurance under severe forced-draft conditions.

THE PROBLEM OF THE WATER-TUBE BOILER—THE HOHENSTEIN BOILER TRIALS.

The present problem of the modern battle ship is not that of the gun and its mount, but the boiler and its installation. The gun is mounted in the most favorable position for care, operation, and inspection, and practically everything on board ship is subordinated to its efficient working. Since a large factor of safety is given to every part of the weapon that is subjected to shock, the gun can only be impaired by incompetence, neglect, or by chemical action of the explosive. Before it is placed in a turret or redoubt it is fully tested, but it is never put on board ship if there is a suspicion that it has been subject to undue strain.

The boiler, on the other hand, is placed beneath the protective deck just above the bilges and near the bunkers. It is installed in compartments that are avoided rather than sought by other than engineer officers. While a careful test is made of the structure before being placed in the vessel, it must necessarily be subjected, even before installation, to conditions that often impair its strength. In its construction many of the plates are subjected to the severest kind of flanging, and its efficient inspection is much more difficult than that of the gun. As there has been a progressive demand for increased steam pressures, the factors of safety used in designing a marine boiler are progressively becoming smaller. The conditions under which the boiler is operated necessarily cause some of the parts to be subjected to rapid corrosion, and only incessant care and attention can prevent the disablement or rupture of the structure.

The experience of the United States Navy with the boilers of the torpedo boats and torpedo-boat destroyers ought to afford some startling evidence as to the manner in which incompetent or untrained men can impair or destroy the efficiency of these steam generators. The agitation in Great Britain over the navy-boiler question ought also to convince naval administrators that the boiler problem is the naval problem of the hour.

In view of the British experience with the Belleville boiler, it is not surprising that the general public of that Empire regard the boiler commission now in session as one of the most important boards appointed by the Admiralty during the past ten years. The membership of this board comprises distinguished experts within and without the naval service. This board has been in session nearly two years investigating the question as to which type of marine boiler is most suitable for use in the navy as the one of approved design. The Admiralty regard the solution of this problem as of vital importance to the efficiency of the British fleet. A series of evaporative and endurance tests of various types of boilers have been made, and the more carefully the question is investigated the more important does it appear in relation to the operation of a modern navy.

The work of the British boiler commission will have a very important influence upon naval construction, since it will cause thoughtful experts to give more attention to the design, construction, installation, and operation of the boiler. One must have experience in the operation of a modern marine boiler to appreciate the intelligence, skill, and care that must be devoted in keeping it in a state of efficiency. The boilers are the lungs of a vessel, although this fact is not generally understood.

While the war ship may be nothing more than a gun platform, it requires considerable power to move a platform of 14,500 tons at a high speed in a heavy sea. This platform is not only expected to be maneuvered rapidly, but to steam uninterruptedly for a distance of one-fourth the way round the world. The battle-ship that can not make the enemy's coast the first line of defense is limited in the field of its usefulness, and when operating at such distance the value of the boiler factor comes only second to the value of the factor of the gun.

The efficiency of the war ship of the several naval powers is simply proportionate to the efficiency of their boilers and the character of their personnel. Neither in armor, armament, or machinery is there any vital difference between the battle ships of the several nations. In these respects, the last ship, wherever designed, is the best, for as regards draft, tonnage, thickness and extent of armor, character and distribution of guns, and design of machinery, every nation has settled upon a type of vessel that meets its particular requirements, and each navy has therefore secured the best war ship for its particular purpose.

The boiler problem, however, has been unsolved. Without taking into consideration the question of personnel, the value of the war ships of the different naval powers can be measured by the efficiency and endurance of the steam generator installed in the vessel. This fact may not be appreciated in its fullness at the present time, but the experience of the coming five years with the ships nearing completion will conclusively show that in coming naval conflicts the question of victory may be quite as much dependent upon the battle of the boilers as the contest between the guns.

With a deep appreciation of the necessity of soon settling upon an approved type of marine boiler for the battle ships and armored cruisers of the United States Navy, the Bureau has invited competition among designers. It believes, however, that, if possible, a boiler of American design should be adopted, and that this marine boiler should be a development of one in general use on shore. By seeking a design that is familiar to thousands of firemen on shore, an important military advantage would be secured, since in time of emergency there could thus be recruited for the naval service water tenders and firemen who had operated almost similar steam generators, and who would therefore require but little training to familiarize themselves with the duty on board ship. While the Navy can and ought to do some efficient work in training firemen, it would be very advantageous to the service if the enlisted force in the stokeholes could have considerable preliminary training with boilers of nearly like design to the one in most extensive use as the approved type for the Navy.

About two years ago the Bureau was informed that an American boiler firm, with considerable financial backing, desired to enter the field of marine-boiler construction. In keeping with the Bureau's policy of inviting competition, encouragement was therefore given the Oil City Boiler Works to design and build a marine boiler and turn it over to the Bureau for test as to its evaporative efficiency and endurance.

The question of entering upon the field of marine-boiler construction had been carefully considered by the Oil City Boiler Works. As the officials of that establishment believed that the time was not far distant when there would be a large demand for marine water-tube boilers, they volunteered to equip an experimental plant at the company's expense. The boiler was of sufficient size to thoroughly test its adaptability for naval purposes. There was therefore constructed a steam generator whose limitations as to weight, height, and floor space were similar to the conditions prescribed for the cruiser *Denver*, and these conditions are in many respects the most severe that have been exacted by the Department. Eighteen months ago the experimental plant was completed, and there was placed at the disposal of the Bureau a boiler of the Hohenstein design.

It was well understood before the Bureau undertook to experiment with this boiler that the character and extent of the data to be collected were to be entirely determined by officials of the Government. In justice to the Oil City Boiler Works it should be stated that every suggestion of the Department was carried out, and that it was the evident purpose of the company to accurately ascertain the requirements of the Bureau, and to discover the greatest difficulties that were likely to be experienced in meeting naval demands. Stated in a business way, the company was willing to expend from fifty to one hundred thousand dollars to ascertain whether or not it would be advisable to extend their plant to enter the field of marine-boiler construction.

In many respects the experimental plant was one of the most complete that has ever been established. The series of tests conducted will command attention in the engineering world, for absolute information has been obtained as to the evaporative efficiency and endurance of the boiler. Information has also been secured in regard to the best means of baffling the gases, thus increasing the evaporative efficiency as well as permitting the boiler to be forced for emergency purposes. Particular care has also been given by the board to the investigation of the circulation of the water, for probably the key to the boiler problem is the question of circulation.

While only seventeen official tests were made with coal as fuel, there were a great many unofficial experiments. Between the several official tests the experts of the Oil City Boiler Works conferred with the Bureau, and therefore each test represents the result of study and experiment. An examination of the data will conclusively show that in many respects the completeness and character of the tests have never been surpassed.

The first six coal tests were run by a picked crew of firemen who had experience in torpedo-boat work. It was believed that these men by training and experience were particularly well fitted to operate the boiler when under severe forced-draft conditions. An experience of a few weeks with this force showed that new methods in firing had to be employed in efficiently operating water-tube boilers, and that the best means of securing efficient work was to have skill and intelligence from those in charge of the fire room and implicit obedience upon the part of the subordinates. The remaining eleven tests were thus made by firemen living in the city, not one of of whom had ever before worked a boiler under forced-draft conditions. The second set of firemen implicitly obeyed orders, and it was therefore possible for the board to have its instructions carried out. A uniform pressure of steam was maintained, as well as a regularity in firing that was productive of good results.

The data secured can be regarded as reliable, for checks and counterchecks were used so that the Bureau could be placed in possession of information that could be relied upon as to completeness and accuracy.

In view of the present condition of this experimental boiler after eighteen months of use with both coal and oil as a combustible, considering the results secured, and by reason of the report submitted by the board which conducted the series of tests, the Bureau has no hesitation in regarding the boiler as the equal in efficiency and endurance of any used in a foreign battle ship.

FUEL OIL TESTS.

THE EXPERIMENTAL PLANT THOROUGHLY OVERHAULED BEFORE COMMENCING LIQUID-FUEL TESTS.

Upon the completion of the coal tests the experimental boiler and various auxiliaries connected with the installation were thoroughly overhauled, so that the plant could be put in condition for carrying on the extended series of liquid-fuel tests contemplated by the Bureau for years, and which were authorized by the naval appropriation bill enacted into law July 3, 1902.

Preparatory to commencing the oil tests the boiler was opened, cleaned, and thoroughly examined. The baffling and lining were renewed where necessary. A cylindrical tank boiler for furnishing steam for spraying purposes was installed, as well as a new compressor capable of delivering air if required at a very high pressure for a spraying medium. An asbestos lining was put underneath the fire brick of the furnace floor.

Close observation was made as to the condition of the tubes. It was found that none of them had buckled or sprung. There was not noticeable any leaks or weeping of seams, rivets, or tube ends, with some trifling exceptions.

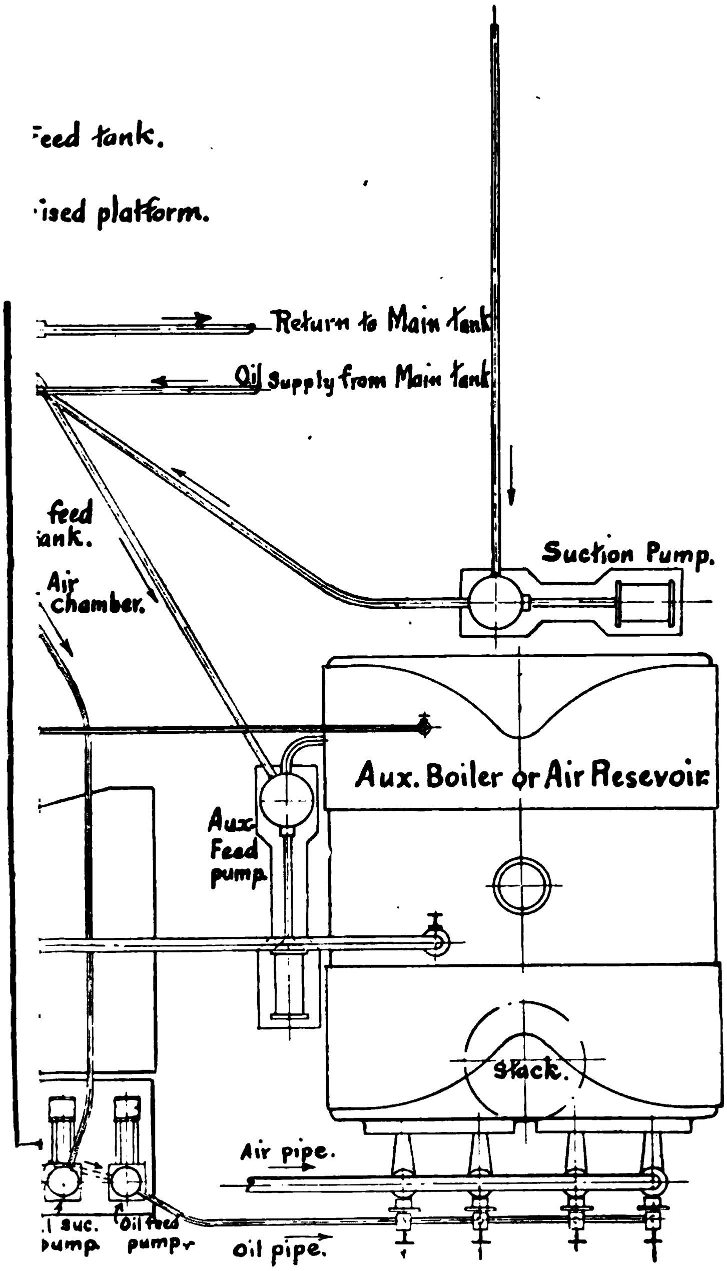
While the official coal experiments only continued for about nine months, the experts of the Oil City Boiler Works had been making preliminary tests for a considerable period previous to the commencement of the official coal experiments. The boiler had thus been subjected to continuous, varied, and at times severe strain for over a year in the conduct of the coal experiments. Particular care was taken before commencing the coal tests to note the condition of every part of the boiler liable to give trouble, so that a fair comparison of the effect of using coal and oil as a fuel could be made.

GENERAL DESCRIPTION OF THE EXPERIMENTAL PLANT WHEN BURNING OIL FUEL.

Fig. 4 is a ground plan of the plant.

Fig. 5 shows the longitudinal section of the experimental boiler with the oil burners in place.

The Oil City Boiler Works Company's design of burner (fig. 6) was used during 33 tests, the remarks of each official test showing the



-eed tank.
-ised platform.
Return to Main tank
Oil Supply from Main tank
feed
-ank.
Air
chamber.
Suction Pump.
Aux. Boiler or Air Resevoir
Aux.
Feed
pump.
Stack.
Air pipe.
-l suc.
-ump.
Oil feed
pump.
oil pipe.

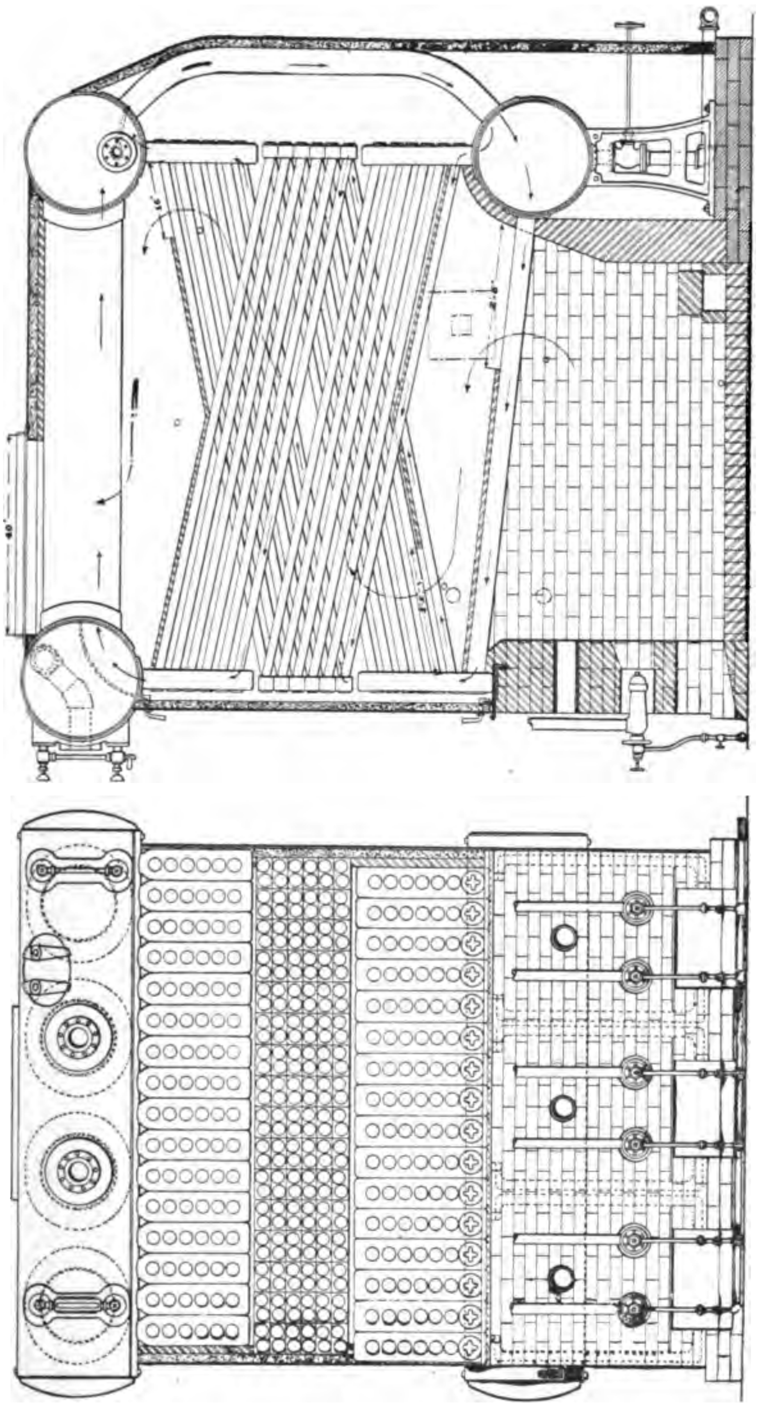


FIG. 5.—The Hohenstein experimental boiler as arranged for the naval liquid-fuel trials. Draft gage connections are shown by the small circles, o; mica windows, or peepholes, are shown by larger circles, ○.

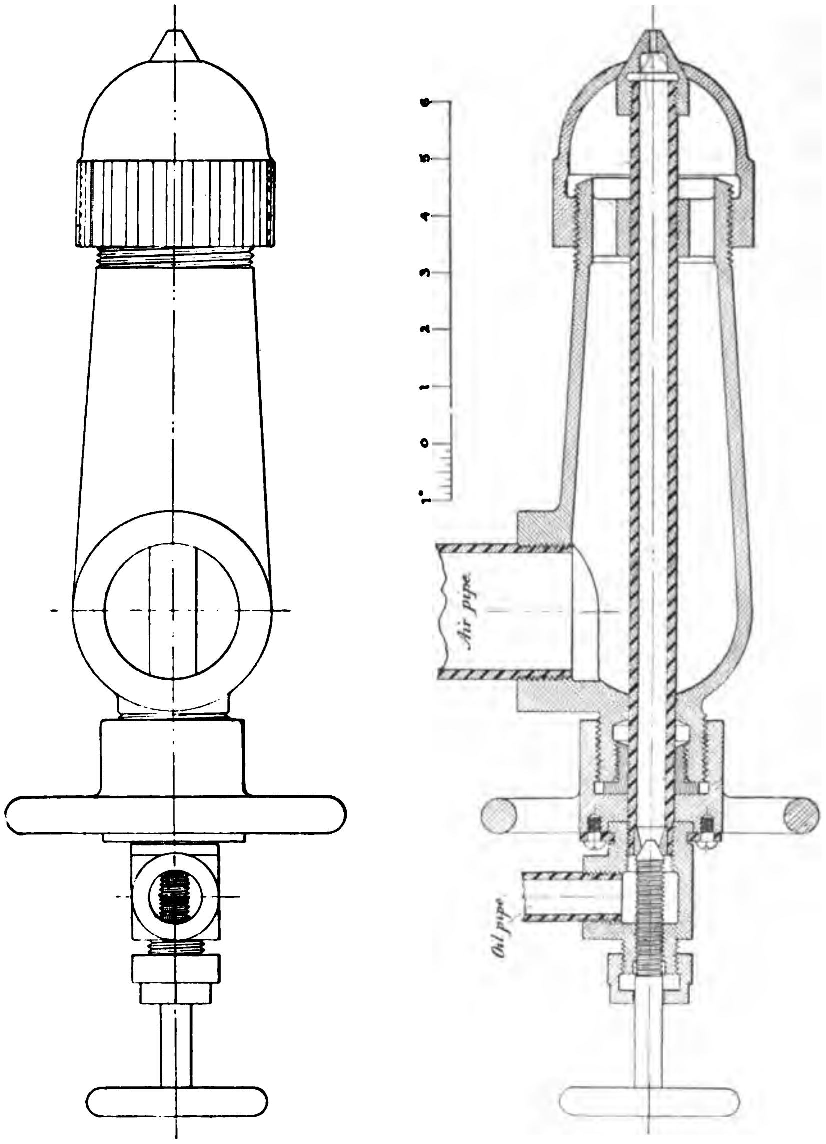


FIG. 6.—The Oil City boiler works burner.

manner in which its installation was modified and changes made in details of construction. Six of these burners spaced 18 inches apart were ranged across the front of the furnace, there being a separate opening in the furnace walls for each burner. Provision was made whereby air could be admitted through the holes as well as through the ash pit. Considering the burners as arranged in three pairs, those of each pair were inclined toward each other at such an angle that their flame impinged near the transverse center line of the furnace.

The burners were so installed that any one could be quickly disconnected or overhauled by the water tenders, and were placed at a height that would make their manipulation comparatively easy. Special precautions were taken that all oil fuel joints were made tight and that no loss would result from leakage.

The arrangements for weighing the feed water were substantially the same as during the coal-burning tests. The facilities for securing various degrees of forced draft were identical with the conditions existing when coal was burned in the furnaces.

METHOD OF WEIGHING OIL USED.

From the storage tank the oil was pumped as desired into a weighing tank, from which it flowed by gravity into the oil-feed tank. From this reservoir the oil was pumped into a pipe leading to the burners, constancy of the pressure being secured by an air chamber and a relief valve. An overflow pipe led from a relief valve back to the feed tank. The weighing and feed tanks were fitted with gauge glasses graduated to 5 pounds, by the aid of which the exact weight of oil was secured at the end of each hour, the same as with the feed water.

The air for atomizing the oil was supplied by a Root blower driven by a direct connected engine. This blower delivered 8 cubic feet of free air per revolution, at pressures ranging from 0.78 pound to 4.68 pounds per square inch. The air pressure was measured by a mercury column, the location of which was such that it gave substantially the same pressure as at the discharge of the blower. The temperature of the compressed air was taken near the same point. A Rand air compressor was also installed, thus enabling higher pressures of air to be used.

The process of getting up steam in the main boiler was somewhat slow, as dependence had to be placed on a small auxiliary boiler for driving the Root blower until sufficient steam pressure could be secured for that purpose from the main boiler. The auxiliary boiler was only equal to the task of supplying the air to two burners.

CHARACTER OF THE OIL USED.

While the Bureau received many offers from various sources to furnish oil free of cost at the wells, careful inquiry showed that there was no certainty when this oil could be delivered at the experimental plant. Since time is a great element in the matter, the board deemed it necessary to use means whereby a steady supply of oil would be assured and no delay ensue from a lack of liquid fuel in the storage tank. The oil was therefore secured from the Standard Oil Company.

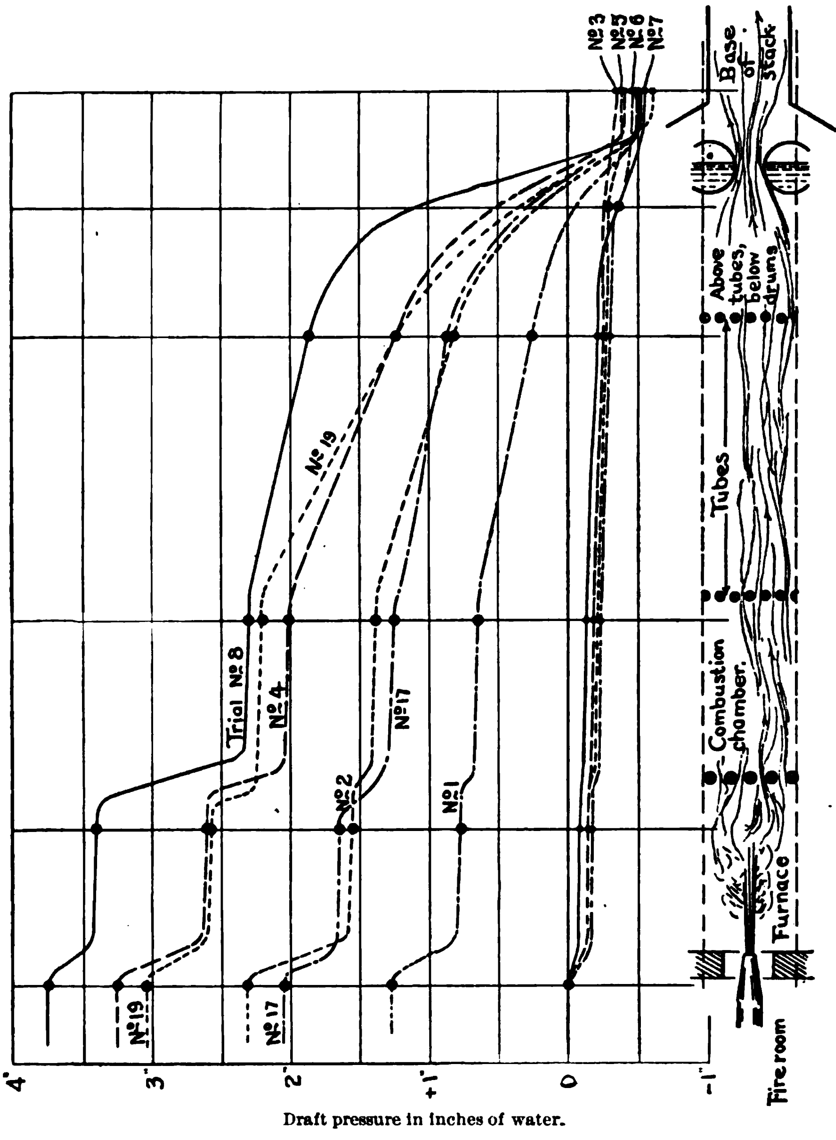
The oil used during most of the experiments was from the Beaumont, Tex., field. It is said to have been subjected to an inexpensive treatment which removed the sulphur and some of the more volatile hydrocarbons. The board believed that it would be best to use an oil that had been thus treated until some positive information could be secured as to whether or not it was safe and advisable to attempt to use crude oil. It should also be stated that delay might have ensued if it had been attempted to depend upon individual shipments. The judgment of the Bureau in this respect was vindicated, for there were times during the tests when others in the city were unable to secure any oil at any price.

CONDITIONS BETWEEN THE COMBUSTION CHAMBER AND SMOKESTACK.

The temperatures in the base of the stack during the oil tests were remarkably free from the rapid fluctuations that characterized the coal-burning trials. There was seldom flaming in the stack, and even then the fluctuations of temperature were absent. The stack temperatures were noted by a mercury-nitrogen thermometer. It was used without mishap throughout the series of trials. Advantage was taken of the constancy of the stack temperature to check the readings of a Brown quick-reading pyrometer. The pyrometer was afterwards used in the furnace and elsewhere to record temperatures that were not excessive. For temperatures higher than 1,600° F. a platinum-rhodium electric pyrometer was used. The measurements secured with this instrument show a maximum furnace temperature of 2,200° F. for both natural and forced draft conditions.

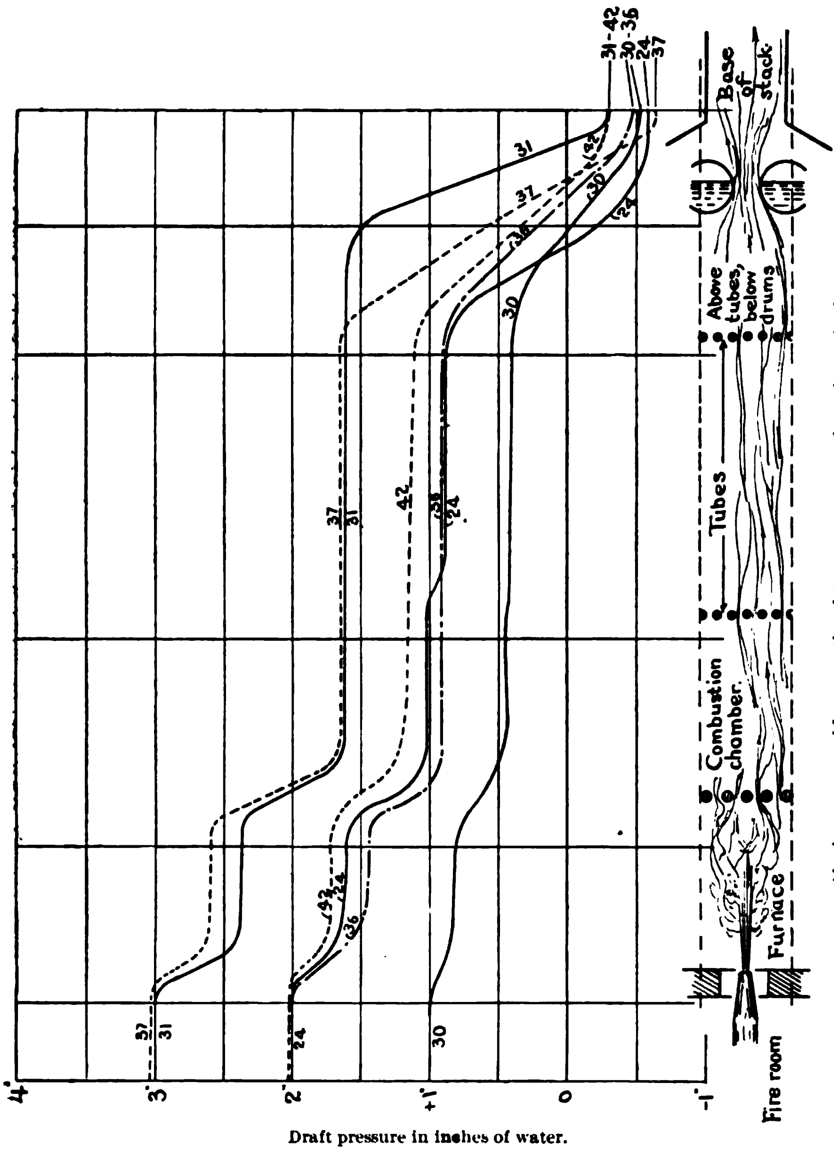
The draft pressures were measured at the same points as in the series of coal-burning tests, and the average readings are shown diagramatically in Figs. 7, 8, and 9.

As an aid to the proper regulation of the supply of oil and air to the burners, a mirror was so placed that the man in charge of the fireroom could quickly note the color of the gases that issued from the top of the stack. The board considered it of great importance that those operating an oil-fuel installation should possess some device whereby the condition of affairs at the top of the stack can be immediately ascertained.



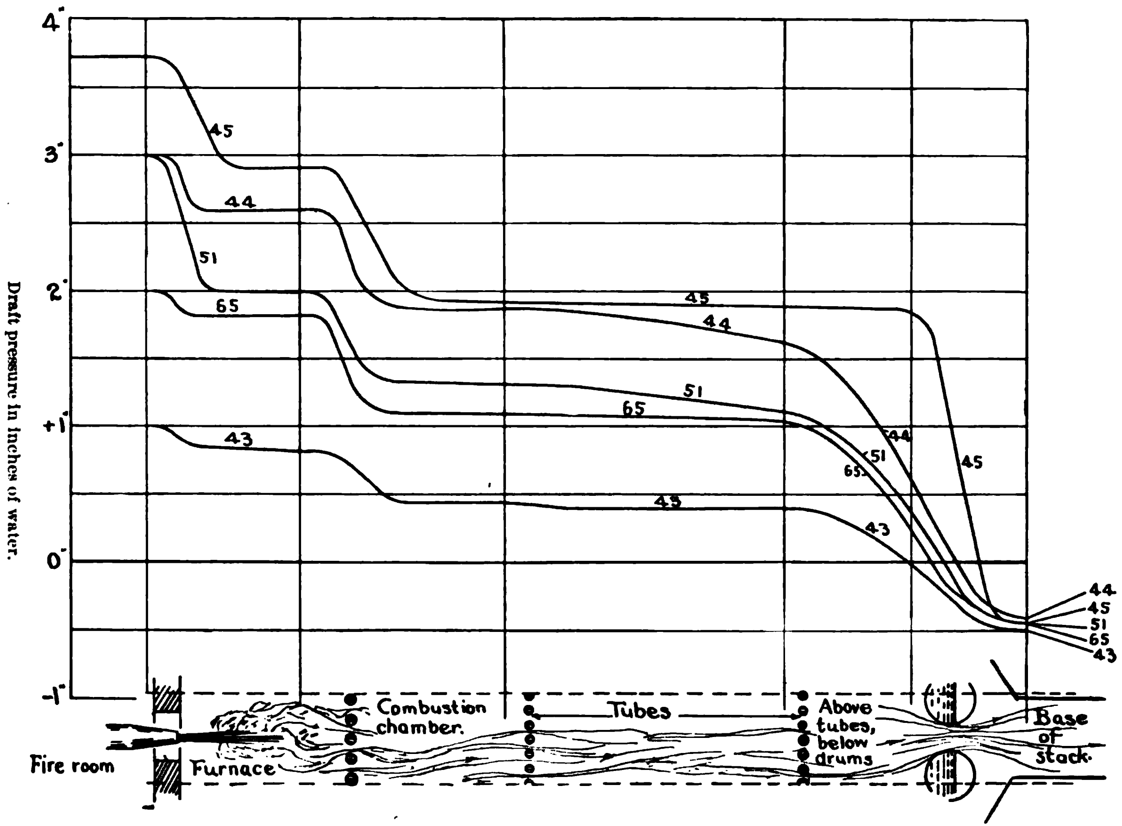
Abscissas are roughly proportional to measurements along the path of gases.

FIG. 7.—Curves showing variation of air pressure within the boiler during certain oil-burning trials. Spots indicate points where measurements were made



Abscissas are roughly proportional to measurements along the path of gases.

FIG. 8.—Curves showing variation of air pressure within the boiler during certain oil-burning trials.



Abscissas are roughly proportional to measurements along the path of gases.

Fig. 9.—Curves showing variation of air pressure within the boiler during certain oil-burning trials.

After considerable study and discussion it was decided that it would be best to give each burner an excess of oil, and this would be shown by the smoke issuing from the stack. Then there was a gradual reduction of the quantity of oil until just a faint trace of smoke could be noticed.

During some of the experiments provision was made for introducing extra air at the sides of the furnace. Holes were cut 8 inches by 1½ inches through the side walls, on a level with the furnace floor and close to its back wall. A flue was built of loose fire brick across the furnace floor, thus connecting the two openings. The roof of the flue had openings between the bricks, thus permitting extra air to be introduced where the combustion was most intense. This extra air supply was cut off during the natural draft and maximum forced-draft trials. The aggregate area of all openings for the admission of atmospheric air into the furnace is given in the detailed report of each trial.

ENDURANCE TEST OF 116 HOURS.

The board particularly deemed it expedient to make an endurance test of the plant. (See Table 6.) A test of this nature was therefore conducted for a continuous period of 116 hours. The torpedo boat *Gwin* was ordered from the Naval Academy, and the torpedo boat *Rodgers* from Norfolk, to assist in the experiments. The day watch of eight hours was conducted by a regular crew of employees of the Oil City Boiler Works, although all the data during this period was taken by observers from the drafting-room staff of the Bureau of Steam Engineering. The crew of the *Gwin* operated the boiler and auxiliaries during half the night, the crew of the *Rodgers* taking the other night watch during the entire test. The data during the night was taken by the leading petty officers of the two torpedo boats, the commissioned and warrant officers in charge of the respective watches checking and verifying the data. The character of the records collected during the night, compared with that secured during the day, shows the material efficiency of the crews of the torpedo boats even as compared with the highly trained force of draftsmen in the Bureau of Steam Engineering.

The test was conducted under the general supervision of the oil-fuel board. The following four commissioned officers had entire charge of the crews and observers during successive watches: Lieut. A. M. Procter, United States Navy; Lieut. G. S. Lincoln, United States Navy; Lieut. William R. White, United States Navy; Lieut. John Halligan, jr., United States Navy. These officers not only supervised the work of the entire watch, but checked the data.

Four warrant machinists, Messrs. Steele, Johnson, Schreiber, and Rowe, were detailed to assist the commissioned officers. These warrant officers were placed in charge of the fireroom.

After a preliminary run for the purpose of training officers and crews in taking data and operating the plant, the test was commenced at noon on August 4. Experts from the Oil City Boiler Works and from the fuel-oil department of the Standard Oil Company were present during each day, and at times visited the plant at night. The members of the board, the commissioned officers in charge of the watches, the warrant machinists in the firerooms, as well as the enlisted force of the torpedo boats, availed themselves of the opportunity to secure advice and assistance from these experts, who, by reason of their training, experience, and opportunity are and ought to be particularly well posted upon the subject. After the first day it was seldom that these experts even offered a suggestion as to operating the burners. They declared that the commissioned officers in charge of the watch and the warrant machinists took such interest in the work and had so quickly grasped the salient points of effecting complete combustion of petroleum as a fuel that it was best to turn over the plant to the sole management of such observing and skilled officers.

The oil burners used during the endurance test were so regulated that they consumed about 830 pounds of oil per hour. Although the data were only recorded at hourly intervals throughout the test, there were unofficial readings and checks made between the hours, thus noting whether uniformity was maintained in the performance of the boiler.

At 10.40 p. m., on August 5, the transformer on the electric-light circuit of the plant was burned out, it having been overloaded by the extra lights installed for night work. Through the resourcefulness of the officers in charge of the test, this accident did not interfere with the endurance trial. Candles and lanterns were quickly obtained from the torpedo boats, so that the appliances could continue to be efficiently operated and the regular data secured.

The smoke issuing from the stack was quite light and uniform in color. From the records of ten observations made during the day watches it appears that the maximum variation was from 0 to 1 by Ringelmann's charts, the average color throughout the day being 0.4.

Temperatures taken with a platinum-rhodium pyrometer showed 1,980° F. near the middle of the furnace. At the receiving end of the combustion chamber the temperature was 1,900° F.

Toward the end of the test the water in the boiler became very muddy. It should be stated that during the entire endurance trial the boiler was fed with Potomac River water that had not been filtered. It might also be stated that during the past eighteen months the experimental boiler has been subjected to just this kind of work, using a quality of water which would have been rejected by many other boiler users.

The notes appended to the coal and oil tests will show in detail the treatment the boiler received. Occasionally the gauge-glass connections would get clogged with mud, and toward the end of the endurance test it was necessary to blow steam through them every half hour.

Two pieces of carbon were removed from the vicinity of the second burner from the left; one piece on August 7 and the other on August 9. Each piece was about 64 cubic inches, and was caused by the burner being so placed as to permit the flame to impinge on the brickwork of the front furnace wall.

CHEMICAL COMPOSITION OF THE OIL USED DURING TESTS COMPARED WITH THE CRUDE PRODUCT.

The character of the oil used during the official tests can be best appreciated by comparing it with the average grade of the crude product. The changes wrought by the refining process can thus be clearly seen by comparing the analyses of the crude Beaumont product and that used in the experiments.

Analysis of Beaumont crude oil.

	Per cent.
Carbon (C)	84.60
Hydrogen (H)	10.90
Sulphur (S)	1.63
Oxygen (O)	2.87

The amount of sulphur in different samples of the crude Beaumont oil varies from 2 to 3 per cent.

Calorific value per pound of combustible	B. T. U..	19,060
Specific gravity		0.924
Flash point	°F..	180
Fire point	do...	200

On distillation at atmospheric pressure to 524° F. it was found that the—

	°F.
First 10 per cent passed over below	428
Second 10 per cent passed over between	428 and 485
Third 10 per cent passed over between	485 and 524
Fourth 10 per cent passed over between	524 and 554

ANALYSIS OF BEAUMONT OIL USED BY LIQUID-FUEL BOARD AS DETERMINED BY THE CHEMIST OF THE NAVY-YARD, NEW YORK.

On distillation at atmospheric pressure to 680° F. it was found that with the oil used during the tests—

	°F.
First 10 per cent passed over between	216 and 482
Second 10 per cent passed over between	482 and 523
Third 10 per cent passed over between	523 and 552
Fourth 10 per cent passed over between	552 and 680

This oil showed on analysis to be composed of the following constituents:

	Per cent.
Carbon (C)	83.26
Hydrogen (H)	12.41
Sulphur (S)	.50
Oxygen (O)	3.83

The sulphur was determined by oxidation with fuming nitric acid in an open capsule.

Specific gravity at 60° F		0.926
Flash point	° F..	216
Fire point	do...	240
Vaporization point	do...	142
Loss for six hours at 212° F	per cent..	21.65

The calorific value of the combustible, calculated on the analysis of the United States Chemist by Dulong's formula, viz:

$$\begin{aligned}\text{British thermal units} &= 14500\ C+62100\ (H-0\ 8)\\ &= 19481.\end{aligned}$$

These analyses show that nearly all the sulphur was removed from the crude petroleum.

ANALYSIS OF CALIFORNIA OIL USED BY LIQUID-FUEL BOARD AS DETERMINED BY CHEMIST, NAVY-YARD, NEW YORK.

The sample consisted principally of high boiling hydrocarbon compound with a small amount of water, and has the ultimate composition:

	Per cent.
Carbon	81.52
Hydrogen	11.01
Sulphur	.55
Nitrogen Oxygen	6.92

It gives the following constants:

Calorific value by Parr's calorimeter	B. T. U..	18,667
Specific gravity at 60° F		0.966
Vaporization point	° F..	230
Flash and burning point	do...	311
Loss for six hours at 212° F	per cent..	12.20

ANALYSIS OF RESIDUUM MIXTURE OF CALIFORNIA AND TEXAS OILS.

The oil used during tests Nos. 68 and 69 were the dregs of the tank, and consisted of a mixture of the California and Texas product. As it has been maintained by some experts that trouble would be encountered in using this mixture, special observation was made as to the manner in which it would burn.

It would also be a matter of interest to consumers of oil to note the evaporative efficiency of such fuel. An analysis of this mixture as made by the chemist of the navy-yard, New York, gave the following results:

	Per cent.
Carbon	84.35
Hydrogen	11.33
Nitrogen	.60
Sulphur	.90
Oxygen	2.82

On distillation the following percentages passed over:

	Per cent.
Between 400° and 450° F	8
Between 450° and 580° F	12
Between 580° and 600° F	30

It has the following constants:

Calorific value by Parr's calorimeter	B. T. U.	19,215
Specific gravity at 60° F		0.966
Vaporization point	° F.	130
Flash point	do.	270
Burning point	do.	280
Loss for twenty-four hours at 212° F	per cent.	14.90

THE HAYES HYDROCARBON BURNER.

The construction of this burner is shown in fig. 10 and the manner of its installation in fig. 11. Part of the air supply is introduced at the sides of the furnace near the back wall. It then passes through heating pipes *AA* to the pipe *B*, the latter extending across the furnace just inside the front wall.

The burners project diametrically through the pipe *B*, and it is contended that the hot air in this pipe will cause the oil to be completely gasified before it escapes from the burner orifices. There is no doubt but that the heating of the air is a direct benefit. Careful and extended experiments will have to be made to show whether this heating could best be effected as in the Howden system of forced draft, or by a simple arrangement of pipes which receive the direct heat of the furnace. The experience of simply heating the pipes during these tests would rather tend to show that this arrangement would not have much endurance. The edges of the holes in the pipe *B* were found somewhat burned upon completion of the official test. If such impairment could occur after the pipe had been in actual service about twenty hours, it is probable that very little endurance can be expected of such an installation under forced-draft conditions.

Two preliminary tests were made. Some representatives of the company owning the burner were present during these trials, and suggestions were sought from them, as they were supposed to have expert

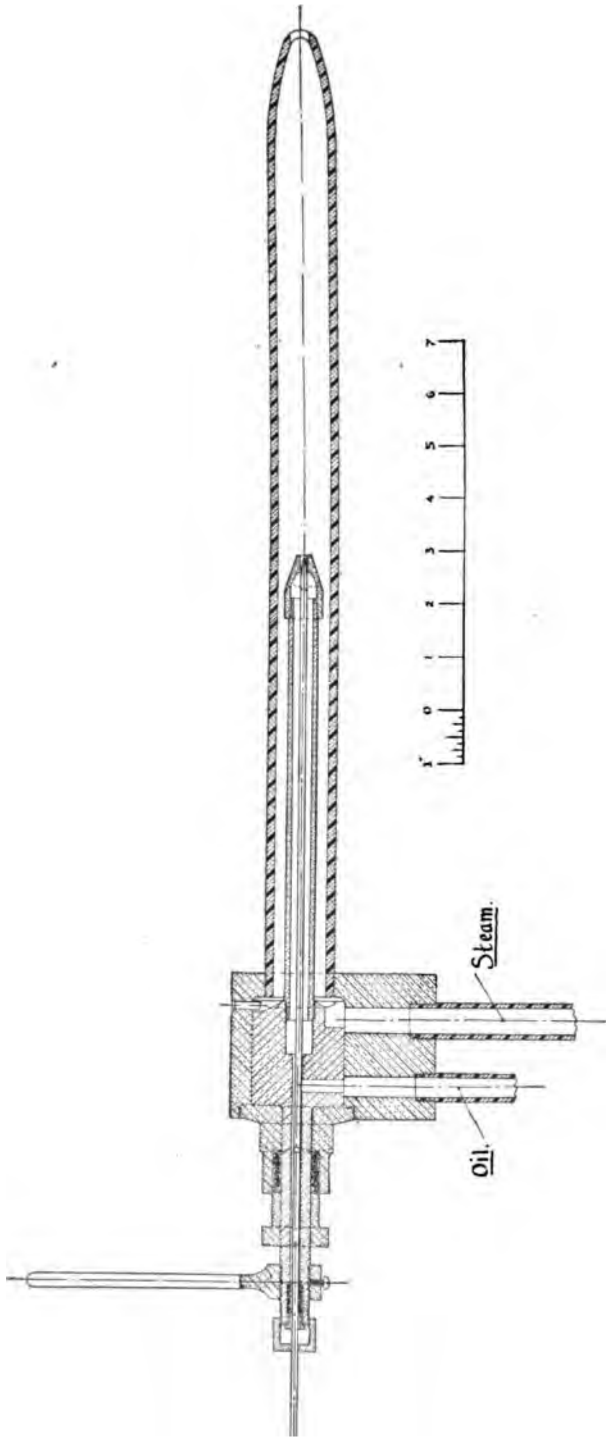


Fig. 10.—The Hayes oil burner, used in test No. 9.

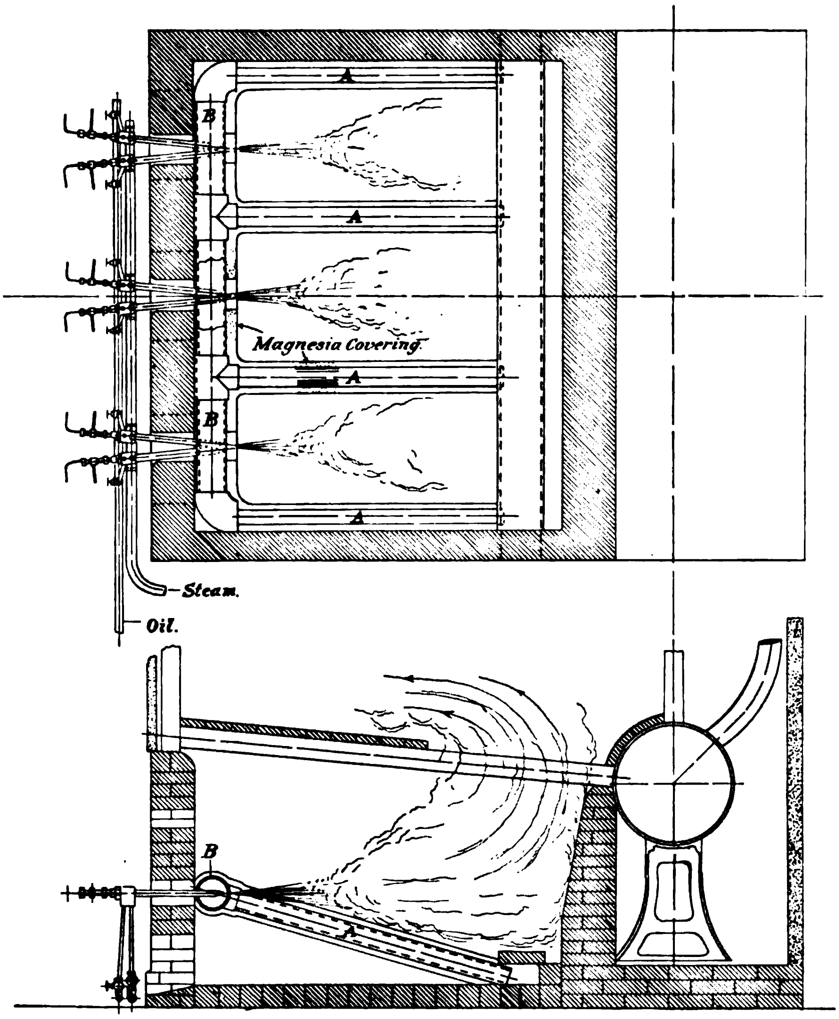


FIG. 11.—Installation of "Hayes" burner, test No. 9.

knowledge of that particular appliance. At no time were they able to secure from the boiler an actual evaporation of 11 pounds of water. During the first experimental trial, on September 10, it was manifest that the bulk of the combustion was above the tubes and in the uptake and stack. In consequence of this loss of heat, and before the second unofficial trial was attempted, the draft opening above the tubes was reduced in the proportion of 16 to 10¼. This caused a noticeable improvement. It should be stated that it required ten days for the company to prepare for the first preliminary trial. Their experts had been furnished blueprints showing in detail the character of the experimental plant, also the position and arrangement of the baffle plates in the experimental boiler. Representatives of the company had also been permitted to witness some of the previous tests. The experience with this company therefor caused the liquid-fuel board to require every inventor to make arrangements whereby he should install his appliance within three days.

Steam for the burners was supplied from an independent boiler at a uniform pressure of 90 pounds. During the unofficial trials the steam was not superheated, the inventor having previously maintained that he could use exhaust steam and attain the object desired. It might also be incidentally stated that the claim was made, that one single burner would consume all the oil that would be required for even forced-draft purposes.

Oil was supplied to the six burners during the unofficial tests at a uniform pressure of 80 pounds. Besides the air introduced through the heating tubes, some additional air was admitted through what were formerly the ash-pit openings. The aggregate area of these ash-pit openings was about 60 square inches.

During the official trial (test No. 9), which continued for six hours, the steam for the burners was superheated. There was fitted, in the opening above the tubes and below the steam drum of the main boiler, 44 feet of 1½-inch pipe. This pipe was in the form of three return bends. Steam from the cylindrical tank boilers was led through this pipe and thence to the burners.

The leading experts of the company did not attend this official trial. The mechanics who installed the burners, however, operated these appliances under the direction of the warrant machinists. The board was informed that it was these mechanics who operated the burners during an official test that had been made at an electric-light station in the city, where it was claimed that there had been evaporated 18 pounds of water per pound of combustible. It is needless to say that no such results were secured under the experimental boiler.

PROGRESSIVE TESTS WITH STEAM ATOMIZING BURNERS.

These tests were made September 19, 20, and 22. One of the special purposes of conducting these trials was to ascertain the exact amount of steam that would be required for atomizing the oil. Every possible check was used to secure trustworthy data. All during the trials there were searches for leaks, but none were discovered.

To ascertain just how much steam was required for atomizing, a separate boiler was installed for generating steam for this purpose. This is a cylindrical return-tube boiler with two plain cylindrical furnaces; and is piped to furnish steam for the oil burners, and has no other steam pipe leading from it. The opening from the safety valve was blanked. This boiler is fitted with two oil burners of Oil City Boiler Works design in each furnace, these burners using air for atomizing purposes. After steam was raised one burner in one furnace was found sufficient to keep the steam pressure uniform.

This auxiliary boiler was put in thorough order at the navy-yard, New York, and carefully made tight at 100 pounds pressure. During the oil-burning test great care was taken to keep both the water level and the steam pressures in this boiler uniform. The water used was carefully weighed in a separate weighing apparatus, in exactly the same manner as the water supplied to the experimental boiler.

The pressure for atomizing purposes on the burners of the experimental boiler, as well as the pressure at which the oil was forced to the burners, was increased each day. It was found that the higher the pressure the greater the amount of water that was evaporated in this main boiler. The efficiency was also slightly greater as higher pressures were used. The percentage of steam required for atomizing the oil, however, also slightly increased as higher pressures were used.

During these tests deflectors were placed in the ash-pan openings, so as to cause the air to be drawn up near the burners, thus effecting combustion nearer the front of the furnace.

The average percentage of steam required for atomizing purposes, as determined from the general range of these tests, was about 4½ per cent of the entire evaporation of the main or experimental boiler.

In these three tests the side burners were directed toward the center of the furnace more than heretofore in order to reduce the amount of heat absorbed by the side walls. The amount so absorbed was judged of by the condition of glow immediately after extinguishing the burners. This glow of the side walls, and also of the back and bridge walls, generally showed a more intense combustion on the right side of the furnace than on the left. The fact that the steam and oil connections to the burners were also at the right side of the furnace front suggests the desirability of proportioning the piping, both as to size and location, so as to get substantially equal pressure at all burners.

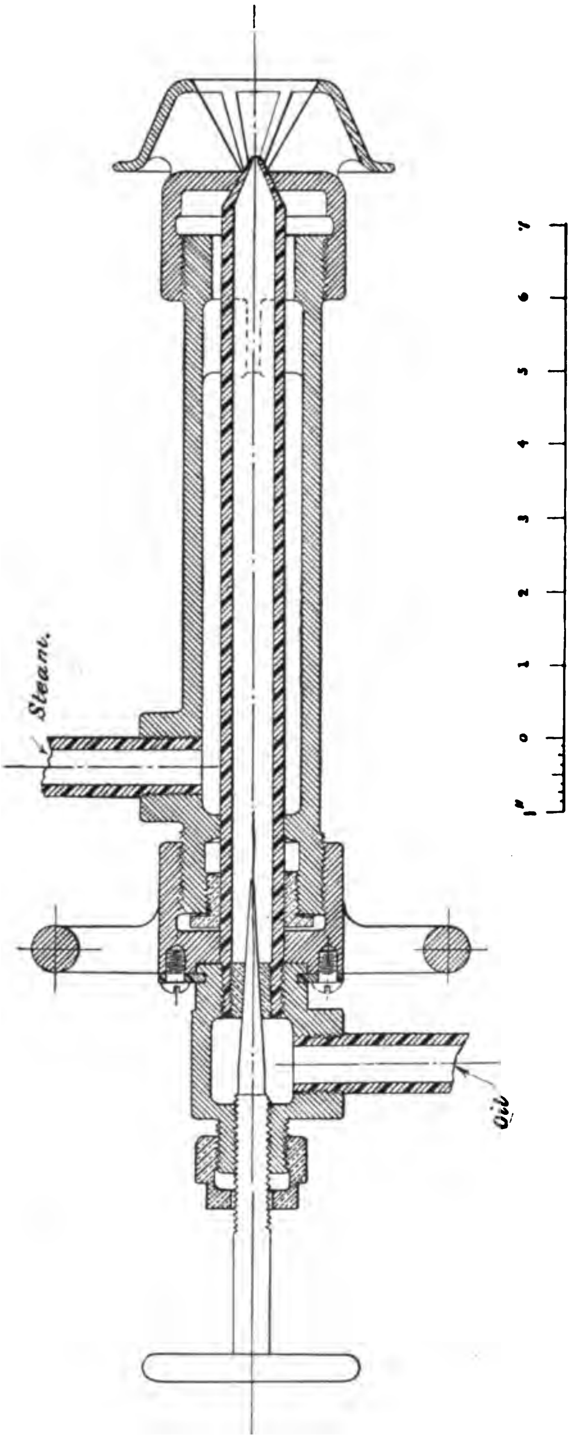


FIG. 12.—The Oil City Boiler Works burner, used in tests Nos. 10, 11, and 12.

Before making further tests the front wall of the furnace was rebuilt with ferruled openings 8 inches in diameter for the burners. Ample latitude was thus allowed for the angular setting of the burners, and there was also opportunity for trying the effect of admitting air around the burners.

An accident to the engine of the fan blower prevented the continuance of these trials with different pressures of forced draft. It should be ascertained just how much steam is required for atomizing purposes when the boiler is forced to its utmost.

The board deems it important, when opportunity will permit, to make an extended series of tests with steam as the atomizing agent. Fresh water can be secured in unlimited quatities at nearly all naval stations, and it might not be a difficult matter to make arrangements whereby the torpedo boats and destroyers, when fitted with fuel oil-burning installations, could be furnished with an ample supply in specially constructed tanks, thus obviating the risk of being compelleo to feed salt water into the boilers.

Even if compressed air should be used on the torpedo boats as the atomizing agent, an accident might happen to the compressor plant which would compel the temporary use of steam. There is therefore an urgent necessity to secure reliable data upon the subject of how much steam is required for spraying purposes under various conditions of natural and forced draft.

THE F. M. REED COMBINED AIR AND STEAM BURNER.

One preliminary and two official tests were made with this burner, whose construction is shown in fig. 13. The "from and at" evaporation during the first official experiment fell short of the best yet attained in these trials (test No. 3) by only about one-half of 1 per cent. On the other hand, the amount of steam consumed in spraying the oil was excessive, being about 1 pound of steam per pound of oil, or several times as much as in test No. 3. Apart from any question of furnace efficiency, the board considers that the combined use of both air and steam in the burners is undesirable. Such an installation more involves unnecessary expense and complication and requires much skill and attention in the adjustment and manipulation of the burners.

The board gave particular attention to watching the operation of this burner, since it is desirious of securing definite information upon the subject as to whether or not it was advantageous to use a combination of both air and steam as the atomizing agent. The inventor personally operated the burner, and every effort was made to reduce the amount of air and steam used for spraying purposes.

The board has no hesitation in stating that combination burners requiring both air and steam together in atomizing will prove unsatisfactory, and that such designs will not only be shown to be the most inefficient, but in all probability the most expensive to install.

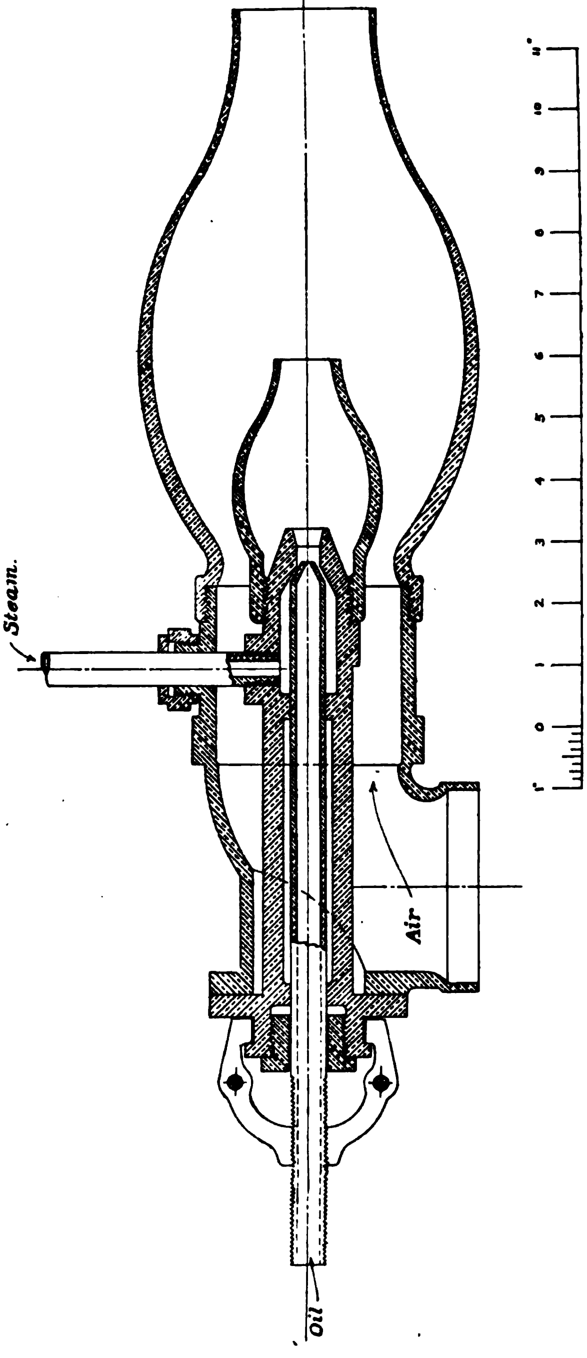


Fig. 13.—The F. M. Reed burner, used in tests Nos. 13 and 14.

THE "HARVEY" SYSTEM.

The general character of the apparatus used with this system is shown in Fig. 14. It was attempted with this process to partially separate the volatile and solid constituents of the oil product, and then burn both the volatile and heavy portions of crude oil simultaneously by forcing the heated gas and residium to the burners at equal pressures.

The system is typical of hundreds of patents taken out attempting to gasify a portion or all of the liquid fuel. It is believed by many inventors that where means are taken to partially gasify the more volatile and explosive hydrocarbons that such action will obviate the necessity of refining crude oil for use as a combustible.

The purpose of the Harvey patent was to pass heated air through crude oil and thus take up a definite portion of the explosive gases of the product. The patentee believed that it was only necessary to admit the hot air at the top of the apparatus and pass it through tubes to the bottom to cause the escaping air to be turned into a rich combustible by taking up a portion of the gases of the fuel. The theory of believing that hot air would be changed into a combustible by simply forcing it through a crude oil product is in a measure justified, but its practical possibilities are more than nullified by the inevitable deposition of the hydrocarbons in the heating or converting devices.

It was further believed that some special value attached to pumping the oil and heated air to the burners at equal pressures. A study of the extended series of tests will show the error of this assumption.

In the Harvey system no particular value is attached to the design and character of the burner. The theory maintained is that by the installation of the carburetor and the regulation of pressures, combined with the use of heated air and oil, that it will be possible to maintain a capacity of evaporation that could not otherwise be obtained. It was likewise assumed that where the explosive hydrocarbons are separated from the other constituent parts of the crude oil that both safety and efficiency in the use of oil would be increased. The inventor believed that he could secure a resultant combustion which was so complete and controllable that any desired degree and capacity of heat could be obtained for welding, forging, or annealing of metals. Particularly was it claimed that there would be a freedom from smoke which would render the system specially adaptable for naval purposes, as well as for many important industries.

There were two tests made with this system—Nos. 33 and 34. In the burner used (fig. 14a) the oil and atomizing agent were admitted in the same direction, and as a result there was very little spraying effect. Good efficiency results were obtained, probably in great part due to the fact that the consumption of oil was not forced. By reason of the size of the carburetor it was not possible to operate the installation under other than natural-draft conditions, and therefore no capacity tests were attempted.

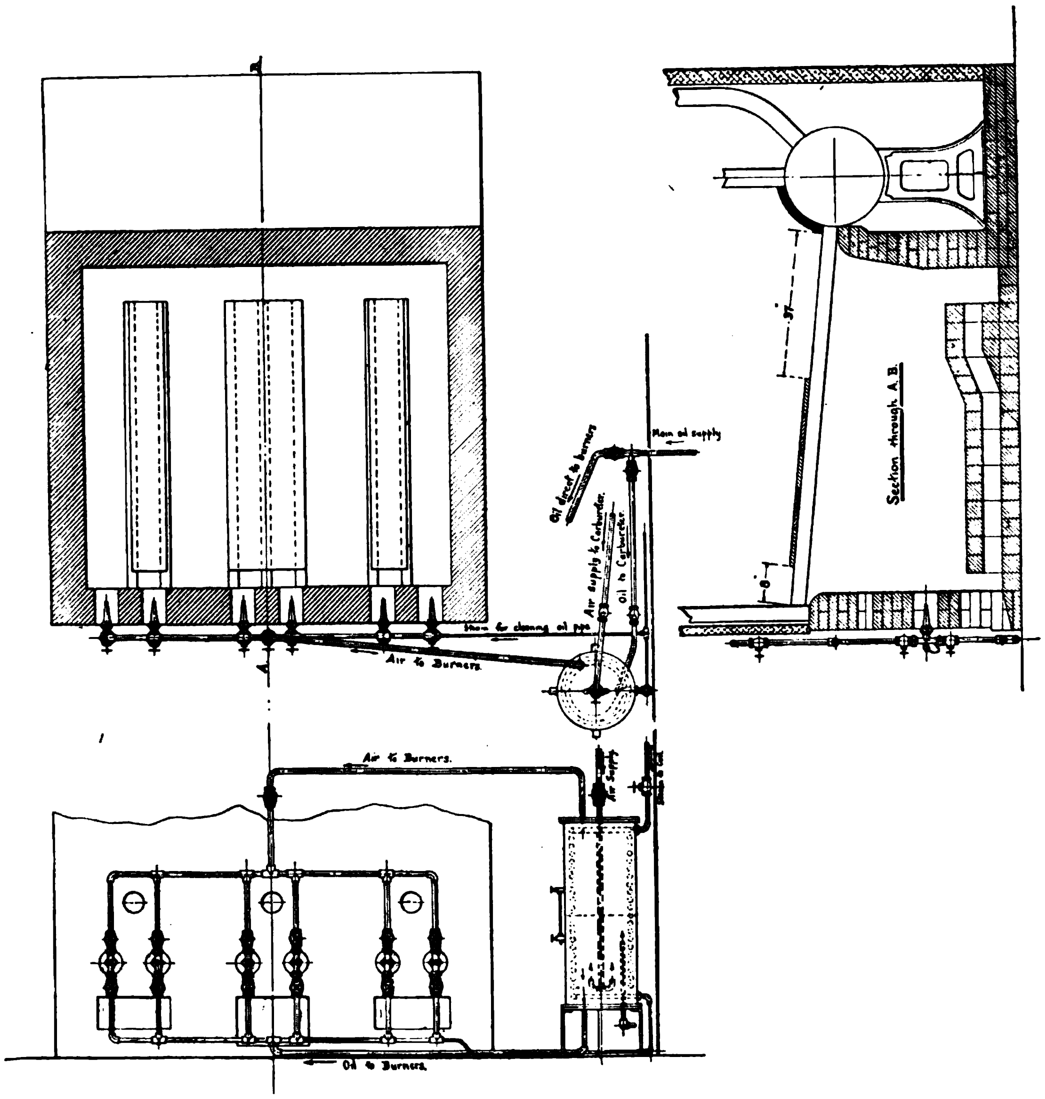


FIG. 14.—Installation of the Harvey process for burning fuel oil.

32196—04. (Faces page 78.)

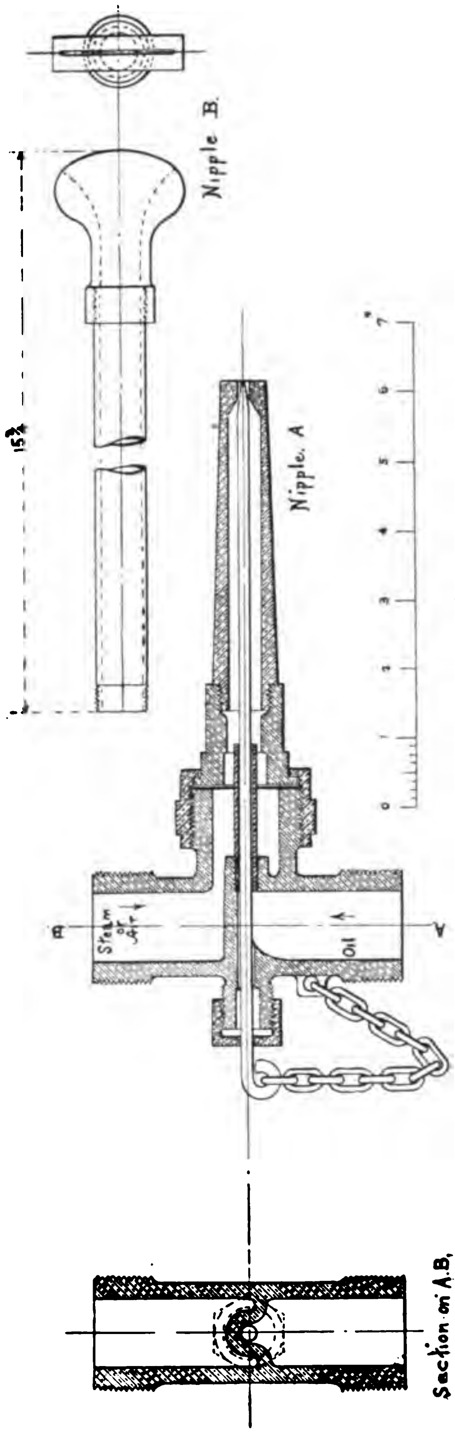


FIG. 14a.—The "Harvey process" burner.

The nipple "B," as shown in Fig. 14a, was used on both official trials.

Probably the best way of showing the results secured with the Harvey system during two tests under natural-draft conditions is to compare the results obtained with that secured during the two natural-draft tests made with the Best burner without such installation.

Type of installation with "Best" burner.	Evaporative efficiency per pound combustible.	Evaporation per square foot of grate surface.	Total evaporation.	Degree of smoke.
Harvey	14.00	261.7	13,120	0.50
Best	13.51	314.8	15,787	.52

A cursory study of these results will show that with the Harvey process there was slightly increased evaporative efficiency over the Best burners, but with a decreased consumption of oil. It need only be stated that with every efficient type of oil burner probably some improvement as regards evaporative efficiency per pound of combustible can be secured in a water tube boiler by decreasing the evaporation per square foot of heating surface.

THE "BRANCH" BURNER EQUIPMENT.

The guiding principle of the Branch system of oil burning is based upon the belief that there should be superheating of the oil fuel as well as of the steam or air used as the atomizing agent. The oil heater consists of two concentric cast-iron cylinders between which there enters the exhaust steam from the various pumps of the installation. The inner cylinder thus forms a receptacle for the oil before being pumped to the burners. The general character of the burner is shown in Fig. 15. Probably the distinguishing characteristics of the burner are simplicity of construction and facility for adjustment.

The company installing this system consider that the burner is a very small determining factor in the use of oil as a fuel. The greatest consideration is given by these experts to the question of the general installation of auxiliaries and piping connected with the equipment. Within the installation are included a regulating valve, relief valve, standard thermometers, pumps, and air compressor. The usual erroneous claim was made that increased heat would be secured through the action of the spraying medium being turned into a combustible when the oil fuel was properly burned with steam or air.

In arranging the installation there was a reduction made in the volume of the furnace and combustion chambers by filling the lower part of the furnace with earth to a level of about 5 inches. In the front of the furnace there was an air uptake as shown in the accompanying sketch. This arrangement was effected at the request of a representative of the company.

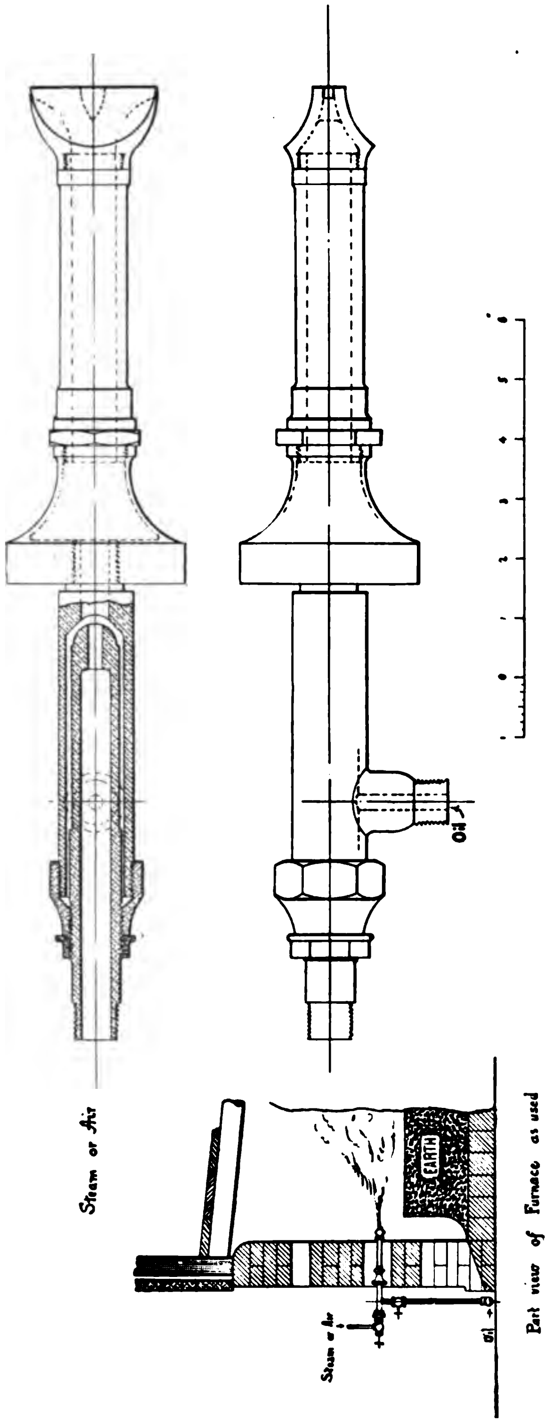


Fig. 15.—The "Branch" oil burner.

The reduction in the volume of the furnace and combustion chamber undoubtedly decreased the evaporative efficiency as well as the output of evaporation. The board, however, believed that experiments should be conducted in various directions suggested by inventors so that the disadvantages, as well as the advantages, of the several arrangements could be more strikingly shown.

There were six tests made of this equipment with the following evaporative results:

Test number.	Evaporative efficiency per pound of combustible.	Evaporation per square foot of equivalent grate surface of furnace for coal burning.	Total evaporation.	Air pressure in fire room.
23	13.11	330.8	16,584	0
24	11.50	458.5	22,982	2
25	11.57	451.8	22,655	2
26	11.20	404.5	20,281	2
27	11.40	476.5	23,893	2
28	11.77	452.0	22,661	2

The above data will show that fairly good efficiency results were secured when the boiler was not forced. In the first test the boiler was run under natural draft, while in all the other tests there was a 2-inch pressure of air in the fire room.

Only four burners instead of six were used during test No. 26. The earth had also been removed from the furnace. The 5 inches in depth of earth which had been placed in the furnace during the previous tests had melted, caked, and decreased to a depth of 3 inches. This earth was red hot eighteen hours after the burners were extinguished. In this test, No. 26, deflectors were placed in the ash-pit openings to direct the entering air upwards.

The feed water used during nearly all the experiments was very muddy, and the experimental boiler was blown down each day to get rid of some of the accumulated deposit. It will be noticed that the capacity of evaporation, as well as the efficiency of the boiler, increased after the removal of all the earth from the furnace.

"ADVANCE" DESIGN OF OIL BURNER.

The general design and arrangement of this burner is shown in fig. 16. In the early experiments with this appliance it was found that the oil was not sprayed sufficiently to produce a jet whereby the combustion would be self-supporting. Fires could only be started by keeping a piece of oil-soaked waste in front of each burner for at least half an hour, during which period the oil burned on the floor

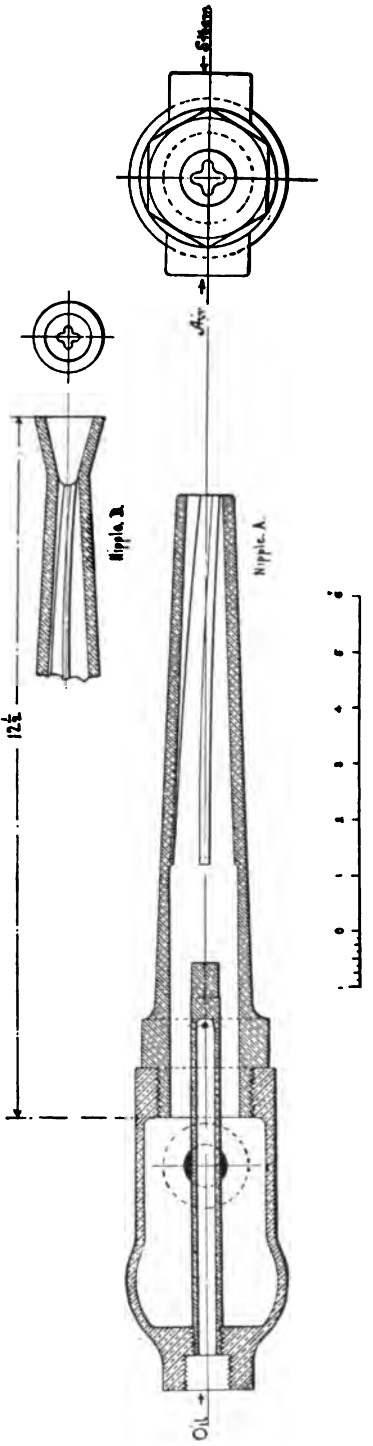


FIG. 16.—The Advance Oil Co. burner.

of the furnace near the back wall. Until the brick lining of the furnace could be sufficiently heated to ignite the oil by radiation, the consumption of liquid fuel was exceedingly limited.

There was no apparent effect due to the rifling of the burner orifice. The jet produced, however, was of great velocity although of small diameter.

The burners required constant attention. An improvement was effected, however, in this respect when the pressure of steam was reduced and the pressure of oil increased.

When burning California oil it was found necessary to enlarge the holes in the oil nipples from one thirty-second of an inch to one-sixteenth of an inch. Extended preliminary tests showed that the best results were secured with this burner, when California oil was used, by operating the spraying medium under about 40 pounds pressure. The efficiency and the capacity evaporation per pounds of water per hour from and at 212° per hour were respectively as follows:

Number of test.	Efficiency.	Evaporation per square foot of grate surface.	Total evaporation.
	Pounds.	*Pounds.*	*Pounds.*
21	14.42	308.8	15,486
22	13.19	285.4	14,311
39	12.51	243.3	12,202
40	12.92	308.5	15,468
41	12.87	280.3	14,059
42	10.57	346.6	17,379
43	11.16	310.9	15,588
44	10.36	413.4	20,728
67	11.86	272.9	13,683
68	12.66	547.8	27,469

SANTA FE OR "BOOTH" TYPE OF OIL BURNER.

This is a slot burner, whose general design is shown in Fig. 17. It is used extensively on the locomotives of the Santa Fé Railway system having been adopted from a design of a burner long in use on the railways of Peru. The Sante Fé Railway Company, through its superintendent of motive power, Mr. George R. Henderson, sent a representative, Mr. C. B. Goode, to install the appliance on the experimental boiler. The Liquid Fuel Board received much valuable information from Mr. Goode, and takes this opportunity of bearing testimony to the many practical suggestions offered by this expert. Having had extended experience in the burning of both Texas and California oils, and having practically tested many forms of arches in locomotive boilers, Mr. Goode was able to show the development that

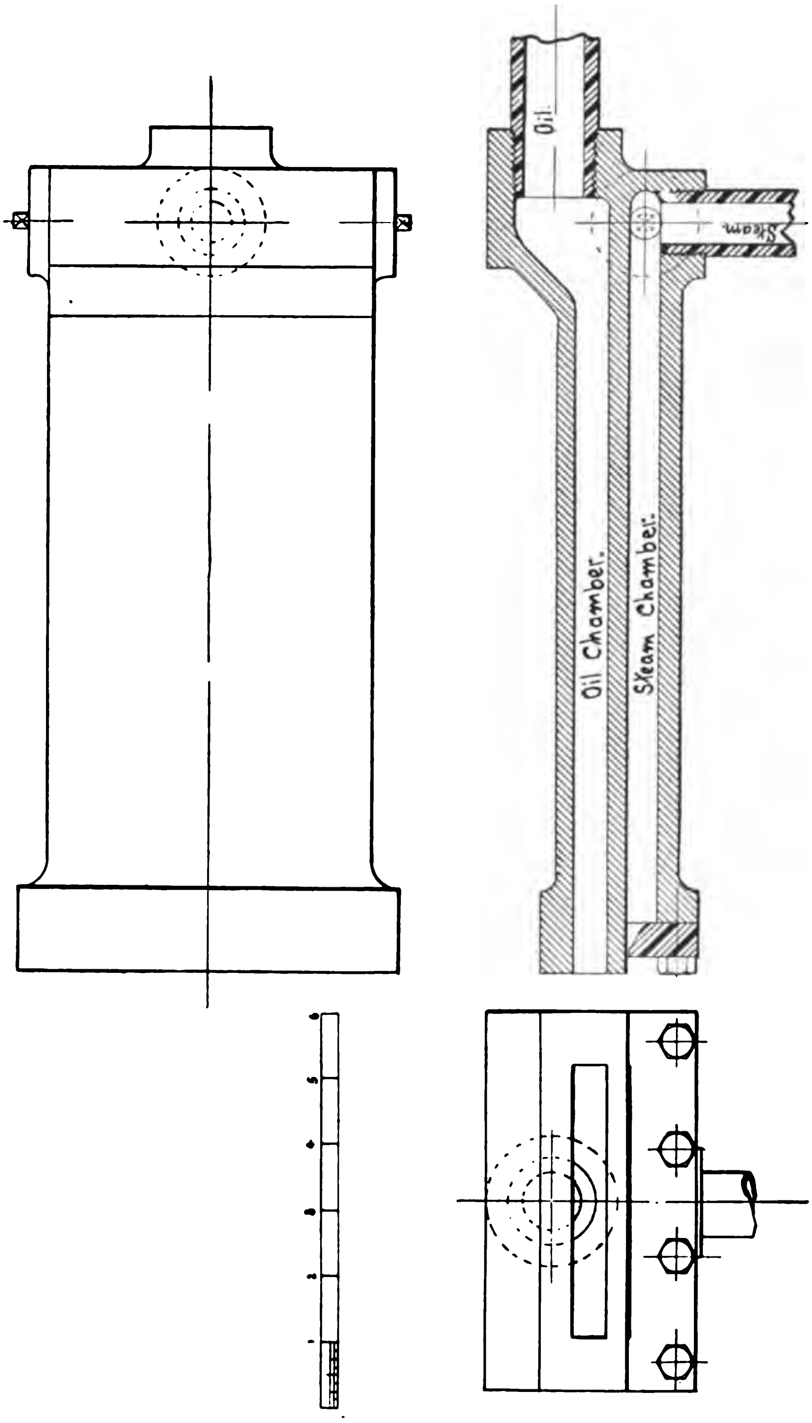


FIG. 17.—The "Santa Fé" oil burner.

had taken place in locomotive work and to point out the similarity in some respects of such practice to conditions approximating to the needs of torpedo boats as regards using crude oil as a fuel in their boilers.

In locomotive work with the Santa Fe burner the greatest efficiency has been secured with some form of arch brick wall. It was attempted to install an arch in the experimental boiler, but the size and character of the furnace, and the difficulty of securing suitable fire brick, seriously interfered with the efficient operation of the boiler. An arch of fire bricks was put up and was used on quite a number of unofficial tests. It broke down after an hour's use, however, on one of the official tests, by reason of the fact that the slabs were too flat to form an arch that would stand severe heat conditions.

A checker-work brick flash wall with a 9-inch overhang was then fitted in the furnace. The air requisite for combustion was admitted just in front of the flash wall through an opening 8 inches wide by 8 feet long after passing under a raised floor of brick tile. This arrangement had the effect of partially heating the air before admitting it into the furnace, and was used throughout the test. The design and arrangement is shown in the sketch appended (fig. 18).

Although the arch was but little used, and consequently the highest efficiency of the burners could not be obtained, there was secured, however, a comparison of the different-sized burners, wherein was shown their relative evaporative values and steam consumption.

The appended table is a résumé of the data secured with this burner. It would seem that with this special burner the Texas oil gave better results than the California product. The heating value of the two oils, however, ought to be very nearly the same, although the Texas oil is somewhat more volatile, with a much lower fire point.

It was suggested by Mr. Goode, that with every leading form of burner, the air necessary for combustion should be admitted into a raised or false floor in the ash pan. This false floor would thus become heated to a high temperature, both by actual contact with the flame and by radiation from the lower row of tubes and baffling. The floor of fire-brick tile would in turn transmit a good portion of its heat to the air passing through it to the furnace. It was further proposed to leave a large number of small openings into this raised floor, and thus allow a portion of the air to come directly up through the openings in the hot tiles. This method, besides distributing the air more evenly throughout the furnace, would probably heat the small jets of air to a higher temperature than could be obtained in any other way. There would also undoubtedly result considerable decrease in the noise experienced with the ordinary arrangement. The observed data will show that the large 5-inch burner gave a better evaporation than the smaller 2-inch burner. Relatively more steam for atomizing purposes was used with the larger burner.

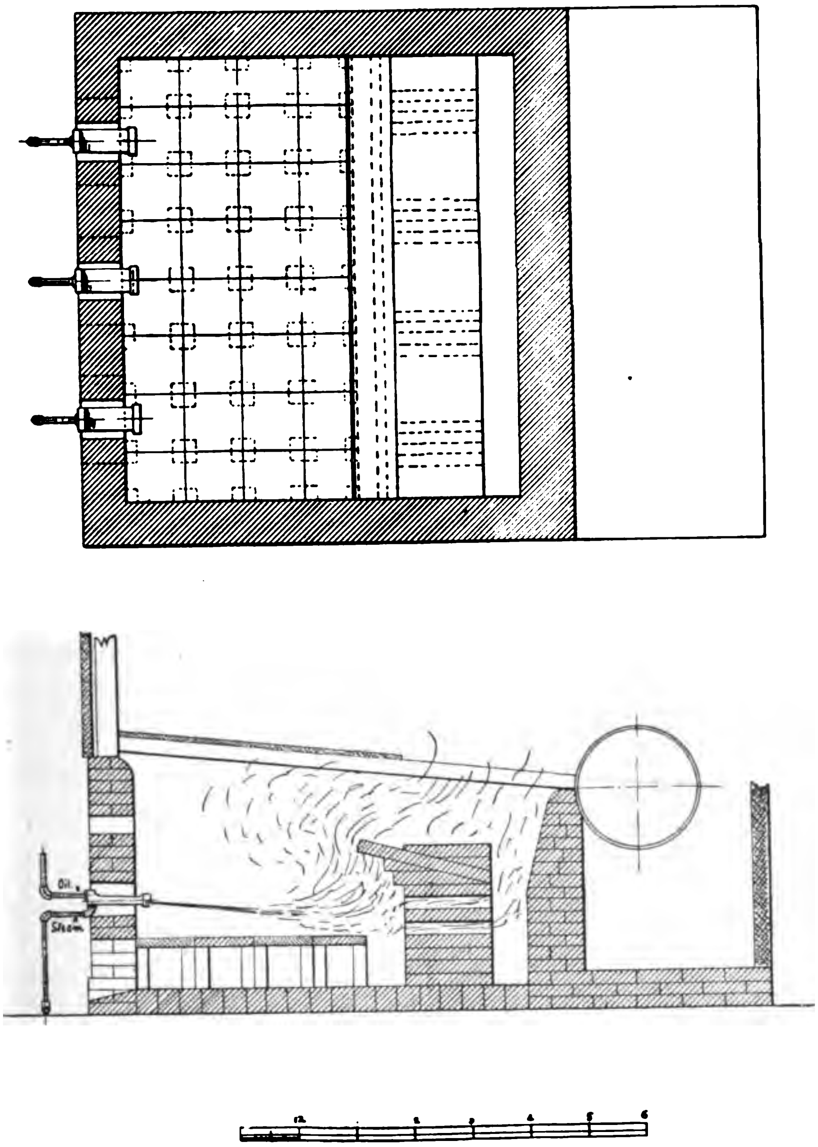


FIG. 18.—Installation of Santa Fé fuel oil burner.

As a result of the observations of the expert of the Santa Fe Railroad Company at the experimental plant, the Board has been informed that the motive power department of that company expects to install an improved form of Booth burner, wherein no arch will be used in the furnace of the boilers, the use of an arch having been found very destructive to crown boltheads in locomotive fire boxes.

General summary of data of the tests of the Booth-Santa Fe oil burner.

Test number.	Date of test.	Duration of test.	State of weather.	Steam pressure per square inch (corrected).	Pressure of superheated steam used for atomizing, per square inch.	Pressure on oil feed line per square inch.	Draft pressure of water in fireroom.	Area of draft opening into furnace.	Air used for combustion per minute.
		Hrs.		*Lbs.*	*Lbs.*	*Lbs.*	*Inches.*	*Sq. in.*	*Lbs.*
46	Apr. 9	8	Clear and warm ...	269.5	90	9.0	0	612	564
47	Apr. 10	4	.....do............	271.5	90	9.0	1	612	962
48	Apr. 17	6	.....do............	273.5	90	10.6	0	612	507
49	Apr. 18	4	.....do............	273.5	90	11.0	1	612	1,008
50	Apr. 20	3	Cloudy	273.5	90	10.0	3	612	1,900
51a	Apr. 21	2	Clear and warm ...	266.5	90	23.6	3	316	915
51b	....do ...	2	.....do............	268.5	90	23.0	3	508	1,473
52	Apr. 22	2	.....do............	267.5	90	23.0	3	316	908
53	Apr. 23	2	Partly cloudy	262.5	90	25.4	3	652	1,875
54	Apr. 24	3	Clear and warm ...	265.5	90	75.0	3	612	1,852

Test number.	Temperatures.					Percentage of moisture in steam.	Height of barometer.	Weight of steam used for atomizer per pound; oil atomized.
	Outside air.		Superheated steam for atomizing.	Chimney gases at base of stack.	Feed water entering boiler.			
	Wet bulb.	Dry bulb.						
	° *F.*	° *F.*	° *F.*	° *F.*	° *F.*		*Inches.*	*Lbs.*
46	64	78	334	462	119	1.69	29.94	1.18
47	65	88	375	578	120	1.64	30.09	.60
48	63	81	334	487	120	1.93	29.77	1.17
49	65	84	352	535	119	1.71	29.79	.77
50	69	84	378	743	117	1.87	29.66	.64
51a	61	83	367	665	120	1.87	29.70	.44
51b	61	83	361	780	123	1.97	29.70	.67
52	59	78	362	767	120	2.03	29.81	.59
53	57	76	356	788	120	1.88	29.90	.52
54	62	86	374	867	120	1.97	30.05	.57

The following table shows the evaporative efficiency per pound of combustible, the evaporative capacity per square foot of grate surface, and the total evaporation secured per hour during the nine official tests conducted with the Booth burner. The results are calculated from and at 212° F.

Number of test.	Evaporative efficiency.	Evaporative capacity per square foot of grate surface.	Total evaporation.
46	13.39	192.2	8,301
47	12.82	335.3	16,813
48	12.88	195.7	9,811
49	12.10	314.6	15,771
50	11.19	447.7	22,448
51	10.29	297.5	14,917
52	10.14	278.8	13,979
53	9.52	251.0	12,585
54	9.62	303.5	15,2[illegible]1

The following curve (fig. 19), as determined from several official tests with the experimental boiler, shows the air requisite for combustion under forced draft conditions:

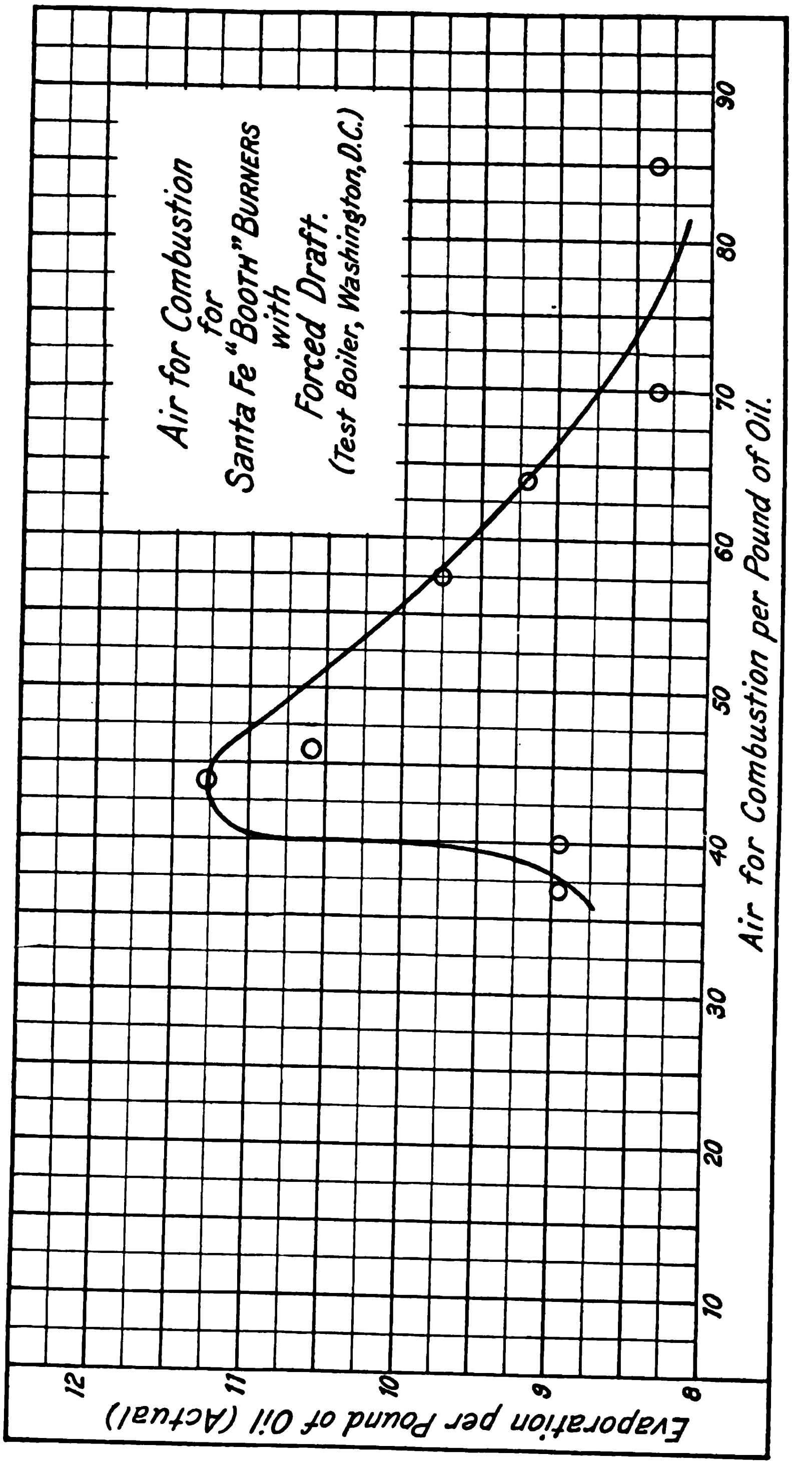
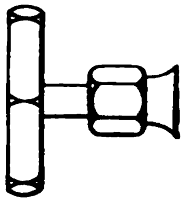


FIG. 19.—Santa Fé Railway burners.



MCDONALD FLUID FUEL BURNER.

Only one test with this burner was made (fig. 20), the duration of the test being four hours. Considerable delay ensued in starting the test, due to the clogging of the burners, thus necessitating the withdrawal of parts of the appliances for cleaning. The average temperature at the base of the stack was only 571°.

By reason of the fact that the burners were of small size, an evaporation of only 9,809 pounds of water per hour was secured. Had there been more burners, or had the burners been of larger capacity, better results might have been secured.

The height of the furnace was hardly sufficient for this style of burner, since the flame impinged directly on the lower row of tubes. The forward end of the burners clogged considerably, and the general unsatisfactory results secured could be attributable to the fact that there were either too few burners, or that they were too small for the work devolving upon them.

THE "W. N. BEST" OIL BURNER.

Eight official tests of this burner were made, its installation having been effected by Mr. Robert W. Gibson, of Palestine, Tex., an expert representing the W. N. Best International Calorific Company, of Los Angeles, Cal. During these tests both steam and air were used as atomizing agents.

This expert had extended experience in the installation and operation of oil-fuel appliances as fitted to locomotives and land boilers, and seemed thoroughly acquainted with developed methods of burning various qualities of oil. During the month that Mr. Gibson was associated with the board he rendered valuable assistance, particularly in the direction of showing wherein locomotive practice as to burning oil fuel might be utilized in effecting a successful installation on torpedo boats.

The board likewise takes this opportunity of giving recognition to the information furnished by Mr. W. N. Best, of Los Angeles, Cal., the inventor of this appliance and an expert whose knowledge of and experience in burning liquid fuel is probably equaled by few persons in this country.

The "Best" burner is a combination of many designs and patents, and like each of the few leading forms is the outcome and development of extended observation and experience. The distinguishing characteristics are as follows:

Admission of air for combustion.—The air should be admitted immediately under the burners, about 1 square inch of opening with ordinary draft being requisite for each 16 pounds water to be evaporated per hour. Wherever it is possible to do so, there should be heating of the air supplied for combustion.

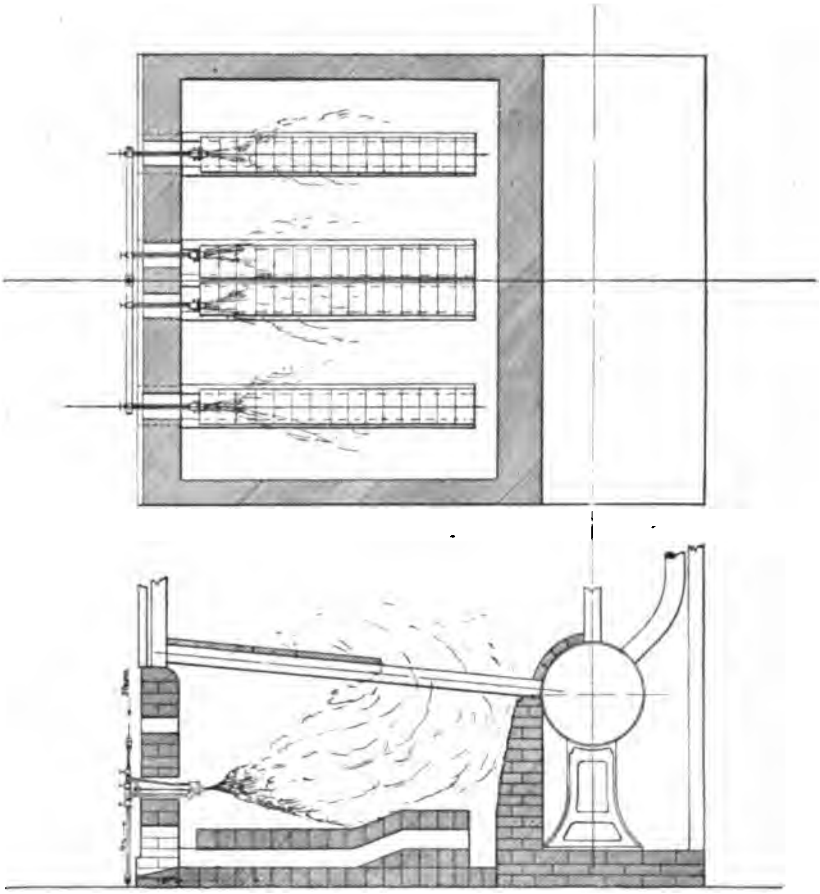


FIG. 21.—Installation of "Best" burner.

The line of blaze.—The burner should be so installed that the line of blaze should strike the base of the bridge wall, provision being made whereby, if necessary to complete combustion, additional air could be supplied near the bridge wall. Special care should be taken that the top of the wall should never be immediately below any horizontal seam of the boiler.

Heating of the oil.—Oil from 15 to 18 gravity (Baumé) should be heated to 120° F. Oil of from 20 to 30 gravity should be heated to 100° F. Oil above 30 gravity need not be heated, since the burner itself is presumed to heat all heavy oils sufficiently.

Construction of the burner.—The burner is of the slot design, the atomizing slot being above the oil-supply passage. This arrangement is supposed to prevent the accumulation of carbon in the oil slot. By thus siphoning in a uniform manner the oil from its supply channel, and arranging for a high velocity of the atomizing agent, the separation of the particles of the liquid fuel can be satisfactorily effected, and thus complete combustion secured. Means are also provided whereby the atomizing channel can be easily cleaned of any scale or other foreign substance without removing the burner from its fixed position.

Only four burners were used, two being installed in the center and one at each end of the furnace. It was a matter of regret to the board that six burners were not installed; for, if this had been done, in all probability there would have been secured with this design of burner possibly the greatest total evaporation from any design of installation. With only one other form of burner during the extended series of tests was the evaporation secured from the Best burner exceeded, and in that case six burners of the other type were used. The forced-draft conditions as applied to naval boilers (where it is expected that double the total evaporation may be secured over that obtained from natural draft) can hardly be appreciated by those unaccustomed to the management of marine boilers. It was this lack of knowledge of excessive naval demands, as regards boiler output under excessive forced-draft conditions, that probably led to the belief that four burners would meet all possible Departmental requirements.

In this instance, as well as in every installation projected, the board urged the fitting of sufficient burners and gave assurance to each exhibitor that the privilege would be given of operating as many burners as was desired. There seemed to be a general inclination, however, to install but a few burners, for the belief is too prevalent that the average oil-fuel burner is capable of developing even as high as 500 or 600 horsepower. It was to dispel this belief that the board permitted an insufficient number of burners to be installed, for it seemed impossible to convince many otherwise apparently well-informed experts that the capacity of every practicable oil-fuel burner was limited.

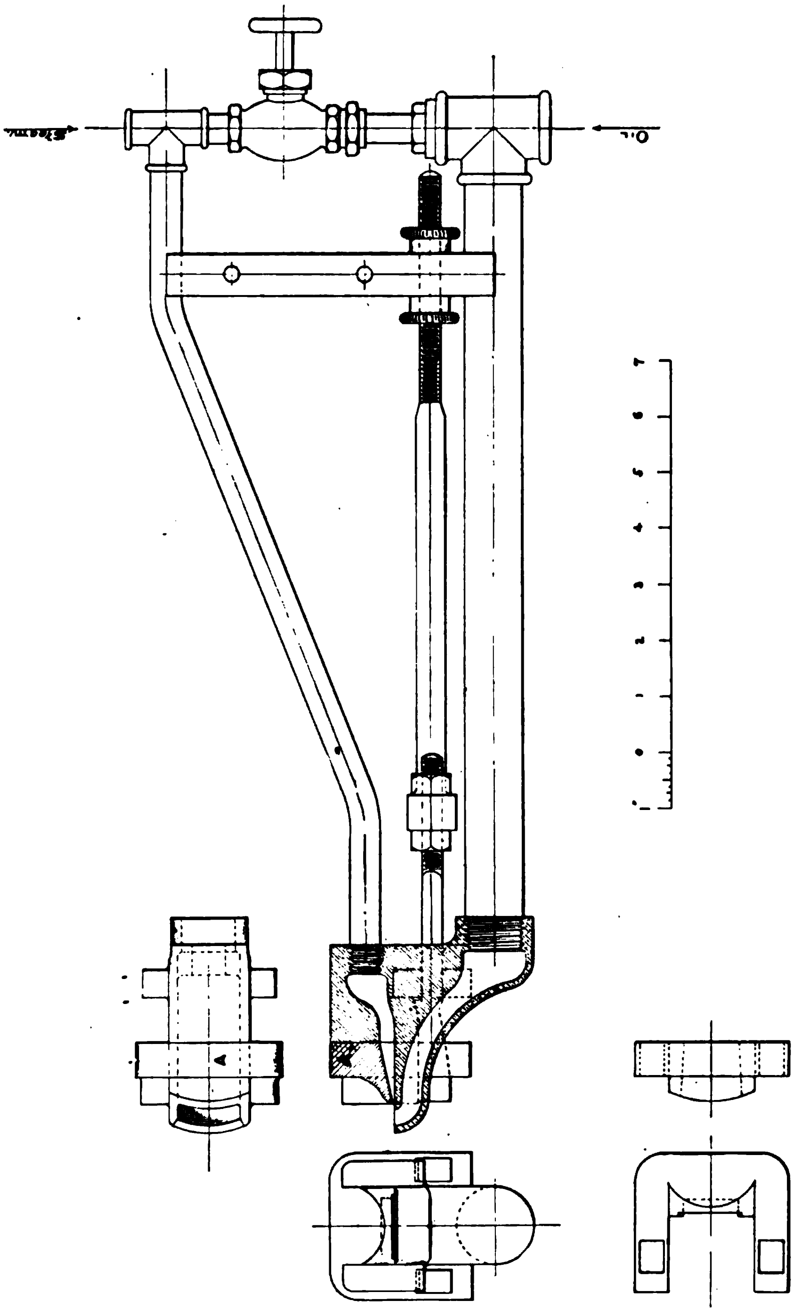


FIG. 22.—The "W. N. Best" oil burner.

The following summary of the tests made with this installation shows that the system is probably one of the best that could be fitted to a boiler for either natural or forced draft conditions. The board desires to emphasize the fact, however, that the general installation as much as the special form of the burner was responsible for the satisfactory results secured.

Test No.	Draft pressure in fire rooms.	Evaporative efficiency.	Evaporation of water per hour per square foot of equivalent grate surface.	Total evaporation of water per hour.
	Inches.		*Pounds.*	*Pounds.*
29	2	11.60	471.9	23,662
30	1	12.33	416.3	20,875
31	3	11.85	587.3	29,452
34	0	13.46	304.2	15,252
35	1	12.37	422.8	21,199
36	2	11.92	467.3	23,428
37	3	11.23	518.9	26,018
38	0	13.57	325.5	16,322

OIL CITY BOILER WORKS BURNER.

Some form of this burner was used on thirty-three official tests, during seven of which a patent nozzle was fitted to the device. The appliance was used on so large a number of experiments in order that comparison might be made as to the relative efficiency and capacity evaporation of both the Texas and California products under various conditions of natural and forced draft.

The Oil City Boiler Works latest improved burner is a development of possibly one or two hundred types that have been used in the oil regions of Pennsylvania and Ohio during the past thirty-five years. While the present device is not a patented article, it is the outcome of extended experiment and experience, and the results secured from its use, whether regarded from the standpoint of efficiency or of capacity, will compare favorably with any type that was used during the trials.

The following summary of comparative tests made with Texas and California oil, when using the Oil City Boiler Works burner, will prove of interest:

Character of oil.	Number of experiments.	Air pressure in firerooms.	Evaporative efficiency.	Evaporation per square foot of equivalent grate surface.	Total evaporation.
Texas	11	0	13.80	271.1	13,288
California	4	0	12.73	242	12,145
Texas	3	1.11	12.17	427	21,548
California	2	1	11.95	363.4	18,220
Texas	4	2.09	11.05	532	25,283
California	3	2	11.47	433	21,760
Texas	2	3.72	11.30	667	33,262
California	3	3	11.20	554.9	27,822

NOTE.—In some of the oil-fuel experiments there were extensions in widths to the bridge wall whereby the volume of the furnace and the equivalent grate surface were somewhat reduced, the board believing that the several inventors should have pretty free scope in this respect. The equivalent grate surface actually represents the horizontal surface that could have been utilized to burn coal had grate bars been in place and coal used as fuel. The figures given are approximately correct.

These results would seem to show that when using this particular design of burner, both from the standpoint of economical efficiency and of capacity, the Texas oil has some superiority over that of the California product. The Texas oil, however, which was used at the experimental plant had undergone a greater degree of distillation, and as the Oil City burner had been particularly designed for burning the lighter product of the Pennsylvania and Ohio yield, it was to be expected that the device would operate better with a distillate from the Texas wells than with a crude product from California. The comparison shows that while with a good form of burner satisfactory results, as regards efficiency, can always be obtained with any kind of oil as a fuel, it is essential to modify the details of construction of burners using a heavy or light crude oil.

A more fair comparison, however, as to the economical efficiency and the capacity of evaporation of the oil products of California and Texas may be made by comparing the results obtained with the Oil City burner when using Texas oil with the Best burner when using the California product.

In comparing the performance of what the board regards as two excellent forms of burners, and both well adapted for marine and manufacturing purposes, it should be particularly observed that there was only an installation of four burners of the Best design as compared with six burners of the Oil City type.

The board had urged the manufacturers of every design to install a sufficient number of burners to meet every probable test requirement. It was by reason of the fact that very few experts believed it possible to secure from a boiler having only 50 square feet of grate surface and 2,175 square feet of heating surface an evaporation exceeding 25,000 pounds of water per hour from and at 212° that they could not be convinced as to the necessity of providing sufficient burners capable of securing such an output of evaporation. The belief is also too prevalent that the average commercial burner has a greater rate of efficiency and capacity than the naval tests proved them to possess.

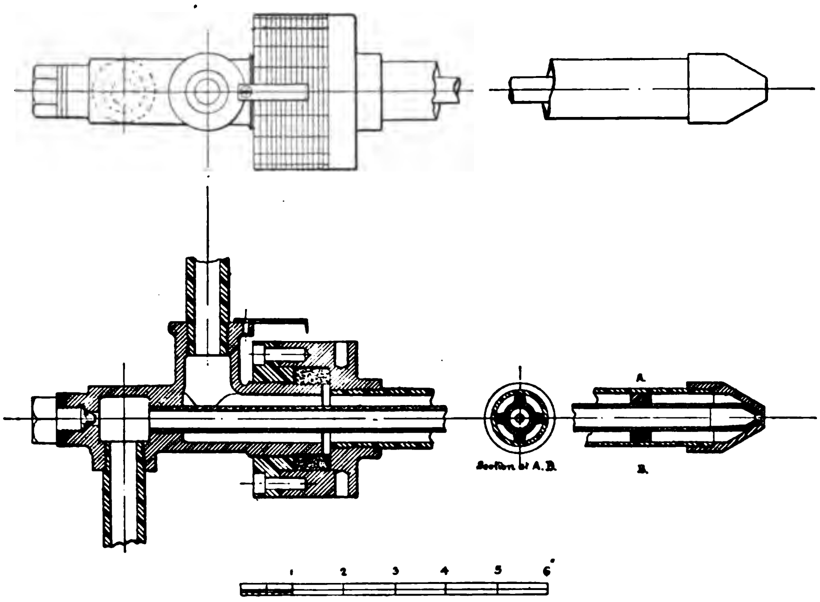


FIG. 23.—Hohenstein-White fuel oil burner.

Unfortunately, therefore, for all interested in the experiments, only four Best burners were brought to Washington, and therefore the board was unable to have an increased installation effected when it was suggested to increase the number to six.

COMPARISON OF RESULTS SECURED WITH AN EASTERN BURNER USING TEXAS OIL, AND A WESTERN DESIGN OF BURNER USING CALIFORNIA OIL.

The following comparison shows that under 1-inch forced draft conditions practically the same efficiency and capacity results were secured with the two burners when using differing oils. Under natural draft conditions the advantage was with the Best burner and with California oil. Under 2-inch draft conditions the advantage was with the Eastern burner and Texas oil. The general results of these three different

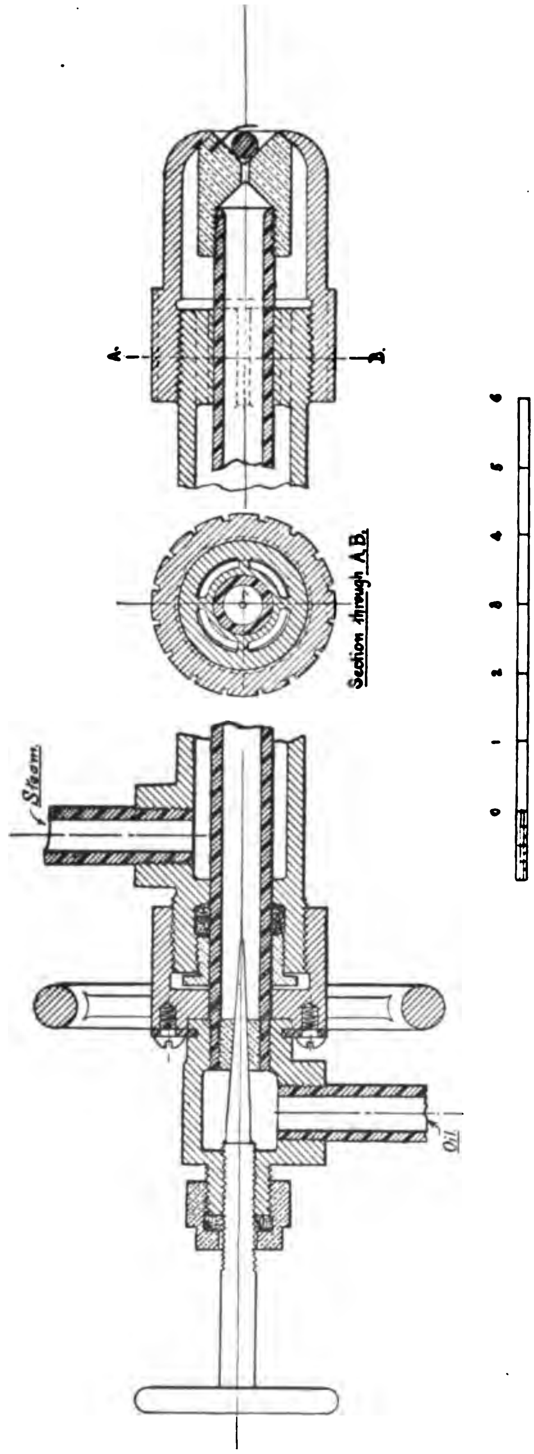


FIG. 24.—Oil City Boiler Works burner, with modified tip.

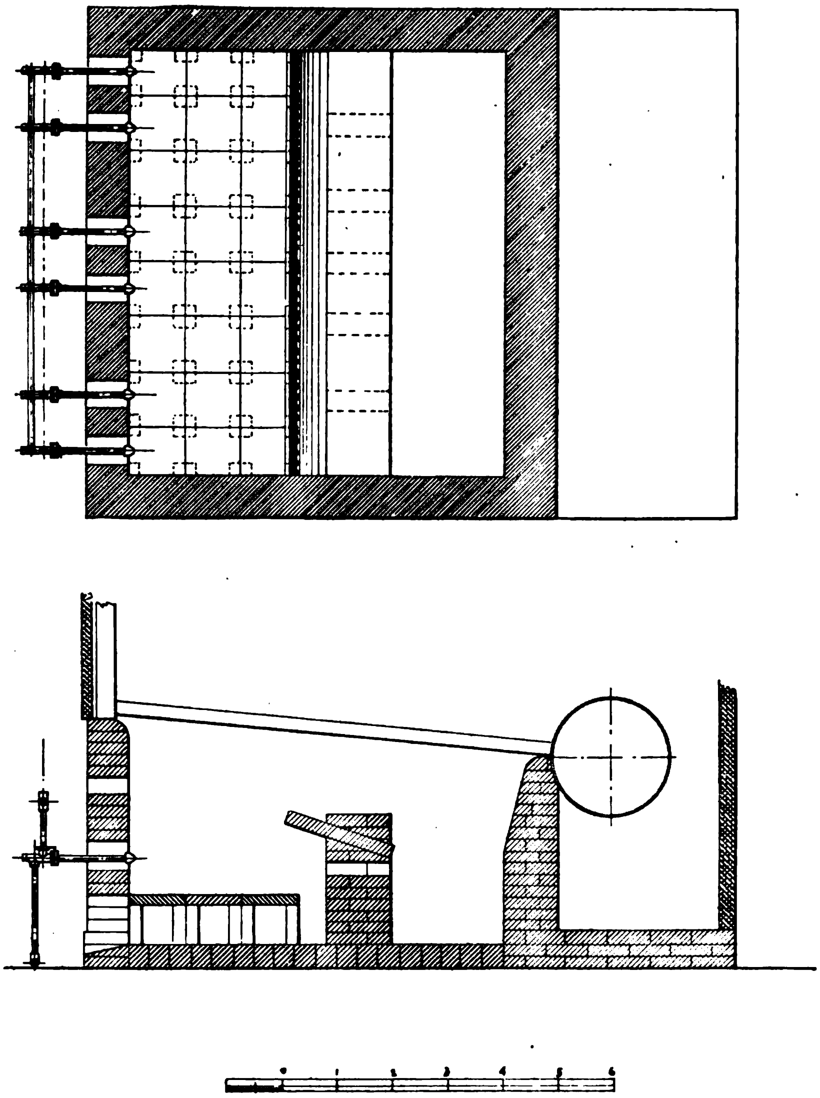


FIG. 25.—Installation of Oil City fuel oil burners.

characters of tests show that the burners are undoubtedly about equal in efficiency and that there was but little difference in the value of the oil from the two localities as measured from the standpoint of weight.

Type of burner.	Number of tests.	Air pressure in firerooms.	Evaporative efficiency.	Evaporation per square foot of equivalent grate surface.	Burners in operation.	Total evaporation.	Oil.
Oil City	11	0	13.80	271.1	6	13,288	Texas.
Best	2	0	13.52	315	4	15,787	California.
Oil City	3	1.11	12.17	427	6	21,548	Texas.
Best	2	1	12.35	419	4	21,037	California.
Oil City	4	2.09	11.05	532	6	25,283	Texas.
Best	2	2	11.76	469.6	4	23,545	California.
Oil City	2	3.72	11.30	667	6	33,262	Texas.
Best	2	3	11.54	553	4	27,765	California.

In regard to the maximum draft tests, the board considers that the decided apparent advantage as regards the capacity evaporation in favor of the Texas product can be accounted for by the fact that a higher fireroom pressure was used when the Oil City burner was in use, and that 50 per cent more burners of this design were in operation. If measured by the standard of number of burners in use, the advantage is with the California oil.

In general it may be stated that it is exceedingly probable that for maximum forced draft purposes the greatest evaporation can be secured from the lighter oils, due to the fact that the oil supply can be more uniformly regulated.

General plan of oil tests.

Test No.	Air or steam for vaporizing.	Type of burner.	Draft.	Hours of run.	Date.	Oil used.
					1902.	
1	Air	Oil City Boiler Works.	1.2 inches	6	June 11	Texas.
2	do	do	2.25 inches.	4	June 12	Do.
3	do	do	Natural	8	June 26	Do.
4	do	do	3.2 inches	3	June 27	Do.
5	do	do	Natural	5	Aug. 2	Do.
6	do	do	do	116	Aug. 4–9	Do.
7	do	do	0.10 inch	6	Aug. 15	Do.
8	do	do	3.75 inches.	3	Aug. 20	Do.
9	Steam	Hayes	Natural	6	Sept. 12	Do.
10	do	Oil City Boiler Works.	do	8	Sept. 19	Do.
11	do	do	do	8	Sept. 20	Do.
12	do	do	do	8	Sept. 22	Do.
13	Air and steam.	Reed	do	8	Sept. 27	Do.
14	do	do	do	8	Sept. 29	Do.
15	Steam	Oil City Boiler Works—Hohenstein.	do	8	Oct. 4	Do.
16	do	do	1 inch	6	Oct. 13	Do.
17	do	do	2 inches	4	Oct. 14	Do.
18	do	do	do	5	Oct. 22	Do.
19	do	do	3 inches	2.5	Oct. 25	Do.
20	do	do	1 inch	7	Oct. 27	Do.
21	do	"Advance"	Natural	7	Nov. 14	Do.
22	Air	do	do	8	Nov. 17	Do.
23	Steam	"Branch"	do	8	Nov. 28	Do.
24	do	do	2 inches	4	Dec. 1	Dc.
25	Air	do	do	2.75	Dec. 2	Do.
26	do	do	do	4	Dec. 4	Do.
27	Steam	do	do	5	Dec. 5	Do.
28	Air	do	do	1.9	Dec. 6	Do.
					1903.	
29	Steam	"Best"	do	4	Jan. 1	Do.
30	do	do	1 inch	6	Jan. 3	Do.
31	do	do	3 inches	4	Jan. 5	Do.
32	Air	Harvey system	Natural	8	Jan. 10	Do.
33	do	do	do	8	Jan. 12	Do.
34	do	"Best"	do	8	Jan. 15	Do.
35	do	do	1 inch	6	Jan. 16	Do.

General plan of oil tests—Continued.

Test No.	Air or steam for vaporizing.	Type of burner.	Draft.	Hours of run.	Date.	Oil used.
					1903.	
36	Air	"Best"	2 inches	5	Jan. 17	Texas.
37	do	do	3 inches	3	Jan. 19	Do.
38	Steam	do	Natural	6	Jan. 20	Do.
39	do	"Advance"	do	7	Feb. 6	Do.
40	do	do	do	8	Feb. 9	Do.
41	do	"Advance" (improved).	do	8	Feb. 13	Do.
42	do	"Advance"	2 inches	4	Feb. 27	Do.
43	do	do	1 inch	6	Mar. 2	Do.
44	do	do	3 inches	3	Mar. 3	Do.
45	do	Oil City Boiler Works—Hohenstein.	do	4	Mar. 14	Do.
46	do	"Booth"—Santa Fe	Natural	8	Apr. 9	Do.
47	do	do	1 inch	4	Apr. 10	Do.
48	do	do	Natural	6	Apr. 17	California.
49	do	do	1 inch	4	Apr. 18	Do.
50	do	do	3 inches	3	Apr. 20	Do.
51	do	do	do	2+2	Apr. 21	Do.
52	do	do	do	2	Apr. 22	Do.
53	do	do	do	2	Apr. 23	Do.
54	do	do	do	3	Apr. 24	Do.
55	do	"MacDonald"	Natural	4	Apr. 27	Do.
56	do	"Oil City"—Hohenstein.	do	4	May 4	Do.
57	do	do	do	6	May 5	Do.
58	do	do	1 inch	5	May 6	Do.
59	do	do	2 inches	4	May 7	Do.
60	do	do	3 inches	3	May 8	Do.
61	do	Oil City "Fitton"	Natural	6	May 22	Do.
62	do	do	1 inch	5	May 25	Do.
63	do	do	2 inches	5	May 26	Do.
64	do	do	3 inches	3	May 28	Do.
65	do	do	2 inches	4	June 2	Do.
66	do	do	3 inches	3	June 3	Do.
67	do	"Advance"	Natural	6	June 11	Do.
68	do	do	3 inches	3	June 12	Mixture, California and Texas.
69	Air	Oil City "Fitton"	Natural	4	June 16	Mixture.

No. 1.—*Test of oil fuel in a Hohenstein water-tube marine boiler June 11, 1902.*

[Six hours' duration with forced draft, using air burners, Oil City Boiler Works burner.]

Time.	Steam pressure by gauge.	Temperature of feed water.	Calorimeter.			Draft air pressures in inches of water.					Oil-spraying air pressure per square inch.
			Higher temperature.	Lower temperature.	Quality of steam.	Fireroom.	Furnace.	Combustion chamber.	Tube chamber.	Base of stack.	
	Lbs.	° *F.*	° *F.*	° *F.*							*Lbs.*
11 a. m.	275	120	402	302	0.982	1.20	0.80	0.60	0.25	0.45	3.20
11.15 a. m.	275	112	402	302	.983	1.20	.80	.60	.25	— .45	3.11
11.30 a. m.	275	112	402	303	.983	1.20	.80	.60	.25	— .50	3.14
11.45 a. m.	275	110	402	304	.984	1.20	.80	.65	.25	— .45	3.23
12 m.	275	122	402	302	.982	1.25	.85	.65	.25	— .45	3.17
12.15 p. m.	275	122	402	303	.983	1.30	.80	.65	.25	— .45	3.17
12.30 p. m.	275	120	402	304	.984	1.25	.80	.60	.25	— .50	3.23
12.45 p. m.	275	112	402	304	.984	1.25	.80	.65	.25	.50	3.23
1 p. m.	275	118	402	304	.984	1.25	.80	.65	.25	— .50	3.23
1.15 p. m.	275	120	402	304	.984	1.25	.80	.65	.25	— .50	3.17
1.30 p. m.	275	120	402	304	.984	1.25	.80	.65	.25	— .50	3.11
1.45 p. m.	275	118	402	304	.984	1.25	.80	.65	.25	— .50	3.23
2 p. m.	275	123	402	303	.983	1.25	.80	.65	.25	— .50	3.23
2.15 p. m.	275	124	402	304	.984	1.30	.75	.65	.25	— .45	3.17
2.30 p. m.	275	122	402	304	.984	1.30	.80	.65	.25	— .50	3.23
2.45 p. m.	275	126	402	304	.984	1.30	.75	.65	.25	— .50	3.23
3 p. m.	275	122	402	303	.983	1.30	.75	.65	.25	— .50	3.23
3.15 p. m.	275	120	402	304	.984	1.30	.75	.65	.25	— .50	3.23
3.30 p. m.	275	128	402	302	.983	1.30	.75	.65	.25	— .50	3.23
3.45 p. m.	275	129	402	303	.983	1.30	.75	.65	.25	— .50	3.23
4 p. m.	275	124	402	303	.983	1.30	.75	.65	.25	— .50	3.23
4.15 p. m.	275	124	402	304	.984	1.30	.75	.65	.25	— .50	3.23
4.30 p. m.	275	121	402	303	.983	1.30	.75	.65	.25	— .50	3.23
4.45 p. m.	275	124	402	303	.983	1.30	.75	.65	.25	— .50	3.17
5 p. m.	275	125	402	304	.984	1.30	.75	.65	.25	— .50	3.17
Average	275	120.7	.....	.....	.9834	1.27	.78	.642	.25	— .488	3.20

State of weather, bright sun, clear sky.
Barometer at noon, 30.02 inches.
Kind of fuel, Beaumont oil.
Revolutions of fan blower, 327 per minute.
Revolutions of Root blower, 126 per minute.
Draft openings into furnace, 666 square inches.

9.10 a. m.: Two middle burners lighted. Root blower driven by steam from small independent boiler.

10.05 a. m.: Steam pressure in main boiler, 100 pounds. All auxiliary machinery begun to be driven by steam from main boiler. All six burners alight.

Smoke very uniform and much thinner than corresponds to chart No. 1.

No. 1.—*Test of oil fuel in a Hohenstein water-tube marine boiler June 11, 1902.*

[Six hours' duration with forced draft, using air burners, Oil City Boiler Works burner.]

Time.	Height of water in gauge glass.	Temperature.			Flue gases.			Oil burned per hour.	Water fed per hour.
		Outside air.	Air in fireroom.	Gases at base of stack.	CO_2.	O.	CO.		
	Ins.	*° F.*	*° F.*	*° F.*	*P. ct.*	*P. ct.*	*P. ct.*	*Lbs.*	*Lbs.*
11 a. m	2.125	84	117					0	0
11.15 a. m.	1.75		118	663	6.8	8.2	(?)		
11.30 a. m.	2.5		116						
11.45 a. m.	3.5		118	705	7.4	8.3	(?)		
12 m.	2.75	86	119					1,769	19,406
12.15 p. m.	1.75		119	709	7.6	9.2	0.4		
12.30 p. m.	2		120						
12.45 p. m.	3		121	717	7	8.6	1.8		
1 p. m	2.13	86	121					1,819	20,023
1.15 p. m.	2.75		122	715	7.1	9.3	1.4		
1.30 p. m.	2.75		122						
1.45 p. m.	3		122	712	7.1	9	1.3		
2 p. m	2.25	86	122					1,776	19,990
2.15 p. m.	2.25		122	711	7.1	8	2		
2.30 p. m.	2.5		122						
2.45 p. m.	2		122	714	6.8	7.4	2.6		
3 p. m	2.75	86	122					1,777	20,000
3.15 p. m.	2.13		122	706	6.6	8.8	1.3		
3.30 p. m.	2.13		122						
3.45 p. m.	2.13		122	690	6.3	9.8	1.7		
4 p. m	2.13	85	122					1,705	18,823
4.15 p. m.	2.13		122	704	6.8	9	1.7		
4.30 p. m.	2.13		124						
4.45 p. m.	2.13		123	709	7	9.6	.8		
5 p. m	2.125	85	124					1,738	19,734
Average		85.4	121	704.6	6.97	8.77	1.5	1,764	19,663

5 p. m.: The floor of the furnace is badly warped from the heat. The floor consists of one layer of fire brick on wrought-iron floor plates on wooden sleepers with dirt rammed between the sleepers. The floor of furnace, back wall of same, and first two baffles are red hot. There are two disk-like accumulations of red-hot carbon on the back wall. The middle and larger one is about 15 inches in diameter.

Next day: The disk of carbon has been removed and examined. Structurally the carbon is indistinguishable from coke. The shape is that of a crater, 5 inches thick around the edges and 2 inches thick in the center. The larger crater was opposite the middle burners. A smaller one was opposite the left-hand burners, and there was practically none opposite the right-hand burners. Evidently a very slight difference of conditions will cause or prevent their formation.

Total pounds oil burned, 10,584.

Total pounds water fed, 117,976.

No. 2.—*Test of oil fuel in a Hohenstein water-tube marine boiler, June 12, 1902.*

[Four hours' duration with forced draft, using air burners. Oil City Boiler Works burner.]

Time.	Steam pressure by gauge.	Temperature of feed water.	Calorimeter.			Draft air pressures in inches of water.					Oil spraying air pressure per square inch.
			Higher temperature.	Lower temperature.	Quality of steam.	Fireroom.	Furnace.	Combustion chamber.	Tube chamber.	Base of stack.	
	Lbs.	° *F.*	° *F.*	° *F.*							*Lbs.*
11.30 a. m.	275	104	402	297	0.980	2.25	1.60	1.50	0.90	—0.50	4.63
11.45 a. m.	275	106	402	301	.982	2.25	1.60	1.50	.90	— .50	4.63
12 m......	275	100	402	302	.982	2.25	1.60	1.40	.80	— .50	4.50
12.15 p. m.	275	102	402	302	.982	2.25	1.50	1.35	.80	— .50	4.26
12.30 p. m.	275	102	404	302	.982	2.30	1.50	1.35	.85	— .50	3.16
12.45 p. m.	275	103	404	303	.982	2.35	1.50	1.40	.85	— .50	4.50
1 p. m	275	102	403	300	.981	2.35	1.50	1.40	.85	— .50	4.63
1.15 p. m..	275	102	402	296	.979	2.35	1.50	1.40	.85	— .50	4.87
1.30 p. m..	275	102	402	296	.979	2.35	1.50	1.40	.85	— .50	4.87
1.45 p. m..	275	104	402	301	.982	2.35	1.50	1.35	.80	— .50	4.87
2 p. m.....	275	108	402	296	.979	2.35	1.55	1.35	.80	— .50	4.87
2.15 p. m..	275	102	402	301	.982	2.30	1.55	1.35	.80	— .50	4.87
2.30 p. m..	275	102	403	302	.982	2.30	1.55	1.35	.80	— .50	4.87
2.45 p. m..	275	104	402	299	.981	2.30	1.55	1.35	.80	— .50	4.87
3 p. m.....	275	105	402	300	.981	2.30	1.55	1.35	.80	— .50	4.69
3.15 p. m..	275	102	402	300	.981	2.30	1.60	1.35	.80	— .50	4.87
3.30 p. m..	275	104	402	278	.969	2.30	1.60	1.35	.80	— .50	4.63
Average...	275	103.2	.....	.....	.980	2.31	1.55	1.38	.83	— .50	4.62

State of weather, bright sun, clear sky.
Barometer at noon, 30 inches.
Kind of fuel, Beaumont oil.
Revolutions of fan blower, 423 per minute.
Revolutions of Root blower, 179 per minute.
Draft openings into furnace, 666 square inches.
9.15 a. m.: Lighted two middle burners.
10.07 a. m.: Pressure begins to show on main boiler steam gauge.
10.30 a. m.: 100 pounds pressure in main boiler. Oil-spraying air pressure, 1.75 pounds.
10.35 a. m.: All six burners alight. All auxiliaries driven by main boiler steam. Oil-spraying air pressure, 2.8 pounds.
10.38 a. m.: 270 pounds pressure in main boiler.
11.30 a. m.: Test begins.

No. 2.—*Test of oil fuel in a Hohenstein water-tube marine boiler, June 12, 1902.*

[Four hours' duration with forced draft, using air burners. Oil City Boiler Works burner.]

Time.	Height of water in gauge glass.	Temperature.			Flue gases.			Oil burned per hour.	Water fed per hour.
		Outside air.	Air in fireroom.	Gases at base of stack.	CO_2.	O.	CO.		
	Ins.	° *F.*	° *F.*	° *F.*	*P. ct.*	*P. ct.*	*P. ct.*	*Lbs.*	*Lbs.*
11.30 a. m.	1.125	82	112	....	......	......	......	0	0
11.45 a. m.	1.13	....	114	785	6.8	9	1.2	....	....
12 m......	1.13	....	116	....	......	......	......	....	....
12.15 p. m.	2.5	....	118	775	7.1	8.6	1.8	....	....
12.30 p. m.	1.13	86	118	....	......	......	......	2,396	25,216
12.45 p. m.	1.5	....	119	775	6.5	8.7	1.4	....	....
1 p. m	1.5	....	120	....	......	......	......	....	....
1.15 p. m..	1.13	....	122	787	7.3	9.2	.8	....	....
1.30 p. m..	1.13	86	123	....	......	......	......	2,300	24,217
1.45 p. m..	2	....	124	795	7.3	8	1.8	....	....
2 p. m	1.13	....	124	....	......	......	......	....	....
2.15 p. m..	1.5	....	125	770	6.9	8.5	1.6	....	....
2.30 p. m..	1.75	88	125	....	......	......	......	2,301	24,361
2.45 p. m..	1.75	....	126	760	6.9	10.5	.6	....	....
3 p. m	1.5	....	126	....	......	......	......	....	....
3.15 p. m..	2	....	126	770	6.9	11.1	.4	....	....
3.30 p. m..	2.125	88	127	....	......	......	......	2,183	23,134
Average ..	....	86	121.5	779	6.96	9.2	1.2	2,295	24,232

12.30 p. m.: The casing of the Root blower being rather warm, some one thought to cool it by playing a hose on it. The result was that the casing got very hot, the speed of the Root blower was reduced, and the oil-spraying air pressure fell to about 2 pounds. Under these conditions, which lasted about ten minutes, the smoke from the stack was very dense. Normal conditions were quickly restored by lubricating the blower impellers with graphite.

1.30 p. m.: There is a red-hot area of about 30 square inches on the outside of the boiler casing opposite the tube chamber. The bulging out of the casing allows the hot gases to take a short cut from the combustion chamber, which is lined with fire brick, to the tube chamber, which is lined with magnesia.

3.10 p. m.: The red-hot area has increased to about 1 square foot.

3.30 p. m., end of test: There is a carbon crater 12 inches in diameter on the back wall opposite the central burners and one 25 inches in diameter opposite the left-hand burners. None opposite the right-hand burners. The smoke during this test averaged about ¼ by Ringelmann's charts.

Total pounds oil burned, 9,180.

Total pounds water fed, 96,929.

No. 3.—*Test of oil fuel in a Hohenstein water-tube marine boiler June 26, 1902.*

[Eight hours' duration with natural draft, using air burners. Oil City Boiler Works burner.]

Time.	Steam pressure by gauge.	Temperature of feed water.	Calorimeter.			Draft pressures in inches of water.			
			Higher temperature.	Lower temperature.	Quality of steam.	Furnace.	Combustion chamber.	Tube chamber.	Base of stack.
	Lbs.	° *F.*	° *F.*	° *F.*					
9 a. m.	275	122	404	305	0.983	—0.15	—0.15	—0.25	—0.35
9.15 a. m.	275	130	404	306	.984	—.15	—.15	—.25	—.35
9.30 a. m.	275	130	404	306	.984	—.15	—.15	—.25	—.40
9.45 a. m.	275	134	404	307	.985	—.15	—.15	—.25	—.35
10 a. m.	275	122	404	308	.985	—.15	—.15	—.25	—.35
10.15 a. m.	275	130	404	308	.985	—.15	—.15	—.25	—.35
10.30 a. m.	275	130	404	308	.985	—.15	—.15	—.25	—.35
10.45 a. m.	275	128	404	308	.985	—.15	—.15	—.25	—.35
11 a. m.	275	140	404	307	.984	—.15	—.20	—.25	—.35
11.15 a. m.	275	125	404	306	.984	—.15	—.25	—.25	—.35
11.30 a. m.	275	130	404	307	.985	—.15	—.20	—.25	—.40
11.45 a. m.	275	124	404	307	.984	—.15	—.20	—.25	—.35
12 m	275	138	404	306	.984	—.15	—.20	—.25	—.35
12.15 p. m.	275	134	404	307	.985	—.15	—.20	—.25	—.35
12.30 p. m.	275	129	404	306	.984	—.15	—.20	—.25	—.35
12.45 p. m.	275	124	404	304	.983	—.15	—.20	—.25	—.35
1 p. m.	275	129	404	307	.984	—.15	—.20	—.25	—.35
1.15 p. m.	275	128	404	307	.985	—.15	—.20	—.25	—.35
1.30 p. m.	275	130	404	307	.984	—.15	—.20	—.25	—.35
1.45 p. m.	275	123	404	307	.985	—.15	—.20	—.25	—.35
2 p. m.	275	122	404	306	.984	—.15	—.20	—.25	—.35
2.15 p. m.	275	130	404	308	.985	—.15	—.20	—.25	—.35
2.30 p. m.	275	136	404	307	.984	—.15	—.20	—.25	—.35
2.45 p. m.	275	124	404	307	.985	—.15	—.20	—.25	—.35
3 p. m.	275	132	404	306	.984	—.15	—.20	—.25	—.35
3.15 p. m.	275	130	404	307	.984	—.15	—.20	—.25	—.35
3.30 p. m.	275	130	404	307	.985	—.15	—.20	—.25	—.35
3.45 p. m.	275	130	404	307	.984	—.15	—.20	—.25	—.35
4 p. m.	275	124	404	307	.985	—.15	—.20	—.25	—.35
4.15 p. m.	275	129	404	307	.984	—.15	—.20	—.25	—.35
4.30 p. m.	275	130	404	306	.984	—.15	—.20	—.25	—.35
4.45 p. m.	275	122	404	307	.985	—.15	—.20	—.25	—.35
5 p. m.	275	122	404	307	.984	—.15	—.20	—.25	—.35
Average	275	128.5	......	......	.984	—.15	—.19	—.25	—.35

State of weather, bright sun, no clouds.
Barometer at noon, 29.70 inches.
Kind of fuel, Beaumont oil.
Revolutions of Root blower, 100 per minute.
Draft openings into furnace, 124 square inches.

No. 3.—*Test of oil fuel in a Hohenstein water-tube marine boiler June 26, 1902.*

[Eight hours' duration with natural draft, using air burners. Oil City Boiler Works burner.]

Time.	Air from Root blower, pressure per square inch.	Height of water in gauge glass.	Temperature.				Flue gases.			Oil burned per hour.	Water fed per hour.
			Outside air.	Air in fireroom.	Gases at base of stack.	Air from Root blower.	CO₂.	O.	CO.		
	Lbs.	*Ins.*	° *F.*	° *F.*	° *F.*	° *F.*	*P. ct.*	*P. ct.*	*P. ct.*	*Lbs.*	*Lbs.*
9 a. m.....	0.73	2.5	72	94	......	90	......	......	......	0	0
9.15 a. m..	.73	2.5	......	97	520	91	6.5	11.5	0.2	......	......
9.30 a. m..	.73	2.5	......	100	......	92	......	......	......	......	......
9.45 a. m..	.67	2.25	......	100	525	94	6.4	11	.6	......	......
10 a. m.....	.67	2.5	74	99	......	95	......	......	......	786	9,503
10.15 a. m.	.79	2.5	......	101	525	96	6.6	10	1.3	......	......
10.30 a. m.	.79	2.5	......	102	......	97	......	......	......	......	......
10.45 a. m.	.73	2.5	......	102	508	98	6.6	10.2	.9	......	......
11 a. m.....	.73	2.5	76	103	......	99	......	......	......	748	9,061
11.15 a. m.	.85	2.25	......	102	500	100	7.1	9.6	.6	......	......
11.30 a. m.	.85	2.25	......	103	......	100	......	......	......	......	......
11.45 a. m.	.85	2.5	......	104	495	100	7.8	9.6	.5	......	......
12 m......	.85	2	78	105	......	102	......	......	......	759	9,537
12.15 p. m.	.79	2	......	105	495	102	7	10.3	.6	......	......
12.30 p. m.	.79	2.25	......	104	......	102	......	......	......	......	......
12.45 p. m.	.79	2	......	106	497	103	7.2	9.3	.9	......	......
1 p. m.....	.79	2.25	80	106	......	103	......	......	......	751	9,895
1.15 p. m..	.79	2	......	108	497	104	7.5	9.5	0	......	......
1.30 p. m..	.79	2	......	109	......	104	......	......	......	......	......
1.45 p. m..	.79	2.5	......	109	495	105	7.8	9.7	0	......	......
2 p. m.....	.79	2.5	82	110	......	106	......	......	......	765	10,066
2.15 p. m..	.79	2	......	109	497	106	7.4	10.6	.3	......	......
2.30 p. m..	.79	2.13	......	111	......	106	......	......	......	......	......
2.45 p. m..	.79	2.13	......	112	497	107	7	11.4	0	......	......
3 p. m.....	.79	2	82	111	......	108	......	......	......	769	9,482
3.15 p. m..	.79	2	......	109	500	108	7.8	10.2	.1	......	......
3.30 p. m..	.79	2.13	......	112	......	108	......	......	......	......	......
3.45 p. m..	.79	2.25	......	110	502	108	7.5	10.5	.2	......	......
4 p. m.....	.79	2.25	82	111	......	109	......	......	......	773	10,373
4.15 p. m..	.79	2.5	......	114	500	110	7.8	9.9	.2	......	......
4.30 p. m..	.79	2.25	......	112	......	110	......	......	......	......	......
4.45 p. m..	.79	2.5	......	112	505	110	7.8	9.9	.4	......	......
5 p. m.....	.79	2.5	82	114	......	111	......	......	......	771	10,083
Average...	.78	......	79	106	503.6	102.5	7.24	10.2	.425	765	9,750

A Brown quick-reading pyrometer placed on the floor of the furnace with the platinum fully exposed to the direct radiations from the flames registers 1,600° F. under the middle burners. At a point about 18 inches in front of the burner tip and 6 inches below its center line the temperature is 1,950° F. The corresponding temperatures for the side burners are about 100° lower. The flames reach for the most part to the middle of the combustion chamber. Only rarely do flames penetrate the tube chamber.

5.10 p. m. The smoke was very uniform throughout the test and so slight as to be barely visible. There are three irregular patches of carbon deposit, one on each side wall of the furnace and one on the back wall. The largest one, on the right side, is dome-shaped, and fully 4 inches thick in the center.

Total pounds oil burned, 6,122.

Total pounds water fed, 78,000.

No. 4.—*Test of oil fuel in a Hohenstein water-tube marine boiler June 27, 1902.*

[Three hours' duration, with forced draft, using air burners. Oil City Boiler Works burner.]

Time.	Steam pressure by gauge.	Temperature of feed water.	Calorimeter.			Draft pressures in inches of water.				
			Higher temperature.	Lower temperature.	Quality of steam.	Fireroom.	Furnace.	Combustion chamber.	Tube chamber.	Base of stack.
	Lbs.	° *F.*	° *F.*	° *F.*						
10 a. m....	275	128	402	298	0.980	3.20	2.75	2	1.25	−0.35
10.15 a. m.	275	122	402	298	.980	3.20	2.75	2.10	1.25	— .35
10.30 a. m.	275	120	402	300	.981	3.20	2.75	2.10	1.25	— .35
10.45 a. m.	275	118	402	300	.981	3.20	2.75	2	1.25	— .35
11 a. m....	275	116	402	300	.982	3.20	2.75	2.10	1.25	— .35
11.15 a. m.	275	118	402	300	.981	3.20	2.75	2	1.25	— .35
11.30 a. m.	275	118	402	300	.981	3.20	2.75	2	1.25	— .35
11.45 a. m.	275	118	402	298	.980	3.20	2.50	2	1.25	— .40
12 m......	275	120	402	298	.981	3.20	2.40	2	1.25	— .45
12.15 p. m.	275	118	402	300	.982	3.20	2.40	2	1.25	— .50
12.30 p. m.	275	116	402	300	.981	3.30	2.40	2	1.25	— .50
12.45 p. m.	275	118	402	300	.981	3.40	2.40	2	1.25	— .50
1 p. m	275	118	402	300	.982	3.50	2.40	2	1.25	— .50
Average...	275	119	......	......	.981	3.25	2.60	2.02	1.25	— .41

State of weather, bright sun, few clouds.
Barometer at noon, 29.94 inches.
Kind of fuel, Beaumont oil.
Revolutions of fan blower, 483 per minute.
Revolutions of Root blower, 219 per minute.
Draft openings into furnace, 666 square inches.

11.20 a. m.: Where the smoke is densest near the stack it has a peculiar pale-blue tint, different from the smoke from a coal fire. It is the color of the smoke as seen against the dark background of the smoke itself—i. e., it is the color by reflected light. The phenomenon suggests that the particles of soot are much finer than in the smoke from coal. Generally the smoke is more like that from a coal fire.

No. 4.—*Test of oil fuel in a Hohenstein water-tube marine boiler June 27, 1902.*

[Three hours' duration, with forced draft, using air burners. Oil City Boiler Works burner.]

Time.	Air from Root blower, pressure per square inch.	Height of water in gauge glass.	Temperature.				Flue gases.			Oil burned per hour.	Water fed per hour.
			Outside air.	Air in fireroom.	Gases at base of stack.	Air from Root blower.	CO$_2$.	O.	CO.		
	Lbs.	*Ins.*	° *F.*	° *F.*	° *F.*	° *F.*	*P. ct.*	*P. ct.*	*P. ct.*	*Lbs.*	*Lbs.*
10 a. m....	3.65	2	.....	102	......	116	......	......	......	0	0
10.15 a. m.	3.65	1.75	80	103	760	119	6.7	11.5	0.5	......	......
10.30 a. m.	3.65	2	.....	106	......	120	......	......	......	......	......
10.45 a. m.	3.41	2	.....	108	785	121	6.9	11	.2	......	......
11 a. m....	3.29	2.5	.....	106	......	121	......	......	......	2,685	27,844
11.15 a. m.	3.16	2	82	107	835	122	7.5	10.3	.2	......	......
11.30 a. m.	3.29	2	.....	108	......	122	......	......	......	......	......
11.45 a. m.	3.29	1.75	.....	109	875	122	8.1	9.8	.4	......	......
12 m......	3.16	2	.....	110	......	123	......	......	......	2,846	29,388
12.15 p. m.	3.10	2	82	111	917	124	8	9.7	.2	......	......
12.30 p. m.	3.16	2	.....	111	......	124	......	......	......	......	......
12.45 p. m.	3.41	1.75	.....	111	950	126	7.7	10.1	.2	......	......
1 p. m	3.65	2	.....	111	......	126	......	......	......	3,071	31,372
Average...	3.37	......	81	108	854	122	7.5	10.4	.3	2,867	29,535

11.43 a. m.: A pane of glass (southwest window), weakened by the direct radiations from a large red-hot area of the casing about 3 feet away, blew out. A board was placed over the opening within fifteen seconds. About one-third of the casing opposite the combustion chamber on the southwest side of the boiler is red-hot. Six bricks, fallen from the second baffle, lie on the floor of the combustion chamber. The Root blower engine crank pin got smoking hot, and a stream of water had to be played on it during the second half of the test. Water leaked from the feed stop valve, but was caught in a pail and returned to the feed tank.

1 p. m., end of test: There is very little caked carbon on the walls of the furnace. The second baffle is badly damaged. Average smoke during the test, 2.5 by Ringelmann charts. As the test progressed the amount of smoke gradually increased from 1 to 4, due, doubtless, to the short circuiting of the hot gases through the damaged baffle.

Total pounds oil burned, 8,602.

Total pounds water fed, 88,604.

No. 5.—*Test of oil fuel in a Hohenstein water-tube marine boiler, August 2, 1902.*

[Five hours' duration with natural draft, using air burners. Oil City Boiler Works burner.]

Time.	Steam pressure by gauge.	Temperature of feed water.	Calorimeter.			Draft pressures in inches of water.			
			Higher temperature.	Lower temperature.	Quality of steam.	Combustion chamber.	Tube chamber.	Above tubes, below drums.	Base of stack.
	Lbs.	° *F.*	° *F.*	° *F.*					
10 a. m....	275	....	405	308	0.985	—0.2	—0.275	—0.30	—0.4
10.15 a. m.	275	130	404	308	.985	— .2	— .275	— .30	— .4
10.30 a. m.	275	124	404	308	.985	— .2	— .275	— .30	— .4
10.45 a. m.	275	123	404	309	.986	— .175	— .275	— .30	— .4
11 a. m....	275	134	404	308	.985	— .175	— .275	— .33	— .4
11.15 a. m.	275	118	404	308	.985	— .175	— .275	— .32	— .4
11.30 a. m.	275	126	404	309	.985	— .2	— .275	— .33	— .4
11.45 a. m.	275	125	404	309	.986	— .2	— .275	— .32	— .4
12 m......	275	122	404	310	.987	— .2	— .275	— .33	— .4
12.15 p. m.	275	132	404	310	.986	— .2	— .275	— .32	— .4
12.30 p. m.	275	132	404	310	.986	— .2	— .3	— .33	— .4
12.45 p. m.	275	127	404	310	.987	— .2	— .3	— .32	— .4
1 p. m	275	136	404	310	.986	— .2	— .275	— .33	— .4
1.15 p. m..	275	140	404	310	.986	— .2	— .3	— .32	— .4
1.30 p. m..	275	138	404	310	.987	— .2	— .3	— .28	— .4
1.45 p. m..	275	136	404	310	.986	— .2	— .3	— .25	— .4
2 p. m	275	140	404	310	.986	— .225	— .275	— .25	— .4
2.15 p. m..	275	110	404	310	.987	— .225	— .3	— .23	— .4
2.30 p. m..	275	124	404	310	.986	— .225	— .285	— .25	— .4
2.45 p. m..	275	136	404	310	.986	— .2	— .285	— .23	— .4
3 p. m	275	134	404	310	.987	— .225	— .3	— .22	— .4
Average...	275	129	......	......	.986	— .201	— .284	— .29	— .4

State of weather, bright sunny day.
Barometer at noon, 30.13 inches.
Kind of fuel, Beaumont oil.
Revolutions of Root blower, 135.8 per minute.
Draft openings into furnace, 275 square inches.

No. 5.—*Test of oil fuel in a Hohenstein water-tube marine boiler, August 2, 1902.*

[Five hours' duration with natural draft, using air burners. Oil City Boiler Works burner.]

Time.	Air from Root blower, pressure per square inch.	Height of water in gauge glass.	Temperature.				Flue gases.			Oil burned per hour.	Water fed per hour.
			Outside air.	Air in fireroom.	Gases at base of stack.	Air from Root blower.	CO₂.	O.	CO.		
	Lbs.	*Ins.*	° *F.*	° *F.*	° *F.*	° *F.*	*P. ct.*	*P. ct.*	*P. ct.*	*Lbs.*	*Lbs.*
10 a. m....	1.46	2.75	82	100	......	107	......	......	......	0	0
10.15 a. m.	1.46	2.75	82	102	565	110	8.2	9.6	0	......	......
10.30 a. m.	1.46	2	83	106	......	112	......	......	......	......	......
10.45 a. m.	1.46	2.75	85	108	550	115	7.8	9.6	.3	......	......
11 a. m....	1.46	2.25	86	109	......	116	......	......	......	984	11,531
11.15 a. m.	1.40	2.25	86	110	550	118	7.8	9.9	.2	......	......
11.30 a. m.	1.40	2.25	87	110	......	118	......	......	......	......	......
11.45 a. m.	1.40	2.75	87	112	555	119	7.8	10.1	0	......	......
12 m......	1.40	2.75	87	113	......	120	......	......	......	935	11,894
12.15 p. m.	1.40	2.75	87	113	560	120	7.7	10.1	.1	......	......
12.30 p. m.	1.40	2.5	88	115	......	121	......	......	......	......	......
12.45 p. m.	1.40	2.25	89	117	563	122	7.9	9.6	.2	......	......
1 p. m	1.40	2.75	89	118	......	123	......	......	......	950	12,047
1.15 p. m..	1.40	2.75	88	116	550	123	7.5	10.2	.1	......	......
1.30 p. m..	1.40	2.75	88	114	......	123	......	......	......	......	......
1.45 p. m..	1.40	2.5	88	112	560	123	7.7	10.5	.3	......	......
2 p. m	1.40	2.5	87	112	......	123	......	......	......	896	11,507
2.15 p. m..	1.40	2.75	87	113	560	123	7.5	10.4	0	......	......
2.30 p. m..	1.40	2.75	87	116	......	124	......	......	......	......	......
2.45 p. m..	1.40	2.75	88	118	558	124	7.3	10.4	.1	......	......
3 p. m	1.40	2.75	88	114	......	126	......	......	......	903	11,550
Average...	1.41	......	87	112	557	120	7.7	10.0	.13	933.6	11,706

The casing and baffles have been overhauled and repaired since the last test (on June 27) and asbestos boards have been placed underneath the fire-brick floor of the furnace. All parts of the casing remained comparatively cool throughout the test.

Temperature in furnace over flames from middle burners, 2,200° F.

Smoke very uniform, averaging 0.4 by Ringelmann charts.

Total pounds oil burned, 4,668.

Total pounds water fed, 58,529.

No. 6.—*Test of oil fuel in a Hohenstein water-tube marine boiler, August 4 to 9, 1902.*

[Endurance test of 116 hours' duration with natural draft, using air burners. Oil City Boiler Works burner.]

Date.	Watch.	Maximum and minimum values observed during each watch.									
						Temperature.				Root blower.	
		Steam pressure by gauge.	Temperature of feed water.	Quality of steam.	Height of water in gauge glass.	Outside air.	Air in fireroom.	Gases at base of stack.	Air from Root blower.	Revolutions per minute.	Air pressure per square inch.
		Lbs.	°*F.*		*Ins.*	°*F.*	°*F.*	°*F.*	°*F.*		*Lbs.*
Aug. 4	12 m. to 4 p. m	275	127	0.986	3.50	93	121	558	122	98	1.34
		275	117	.984	2	88	110	550	106	85	.85
	4 p. m. to 12 p. m..	275	119	.987	4	88	124	575	126	99	1.40
		275	116	.986	2	75	110	558	110	97	1.28
Aug. 5	12 p. m. to 8 a. m..	275	122	.986	3	80	112	575	112	98	1.34
		275	117	.986	2	70	104	572	104	90	1.22
	8 a. m. to 4 p. m...	275	122	.986	3.25	88	120	590	122	104	1.34
		275	112	.986	2.50	80	108	570	108	92	1.22
	4 p. m. to 12 p. m..	275	120	.987	2.75	88	120	590	122	100	1.34
		275	118	.986	2	80	116	585	118	97	1.34
Aug. 6	12 p. m. to 8 a. m..	275	122	.987	3	82	116	610	118	104	1.40
		255	102	.985	2	73	104	585	107	84	1.22
	8 a. m. to 4 p. m...	275	120	.987	5	95	125	610	122	104	1.34
		255	102	.985	2.50	73	108	565	112	91	1.16
	4 p. m. to 12 p. m..	275	130	.987	3.50	73	112	605	118	104	1.40
		270	112	.985	2.50	72	104	565	106	90	1.16
Aug. 7	12 p. m. to 8 a. m..	270	124	.987	3	74	116	598	114	100	1.40
		270	118	.986	2	69	107	590	110	92	1.22
	8 a. m. to 4 p. m...	276	128	.987	4	90	116	600	114	100	1.40
		270	112	.985	2	74	108	585	108	95	1.22
	4 p. m. to 12 p. m..	275	124	.985	4	81	118	595	116	100	1.40
		270	110	.985	2	74	100	595	108	97	1.34
Aug. 8	12 p. m. to 8 a. m..	275	124	.985	3.75	74	106	595	108	103	1.40
		265	119	.983	1.50	70	98	550	101	92	1.34
	8 a. m. to 4 p. m...	274	128	.985	3.75	88	119	625	124	95	1.40
		272	114	.983	1.50	73	101	565	102	92	1.28
	4 p. m. to 12 p. m..	274	125	.983	2.50	87	121	605	129	102	1.40
		271	116	.982	1.75	74	111	585	110	92	1.40
Aug. 9	12 p. m. to 8 a. m..	275	128	.982	3	80	118	590	116	95	1.40
		273	120	.982	2	74	103	590	105	94	1.34
	Average of hourly observations.....	273	119.4	.985	....	79	112	585	113.5	96	1.31

Kind of fuel, Beaumont oil.
Draft openings into furnace, 348 square inches.
Total pounds of water fed, 1,192,482.

No. 6.—*Test of oil fuel in a Hohenstein water-tube marine boiler, August 4 to 9, 1902.*

[Endurance test of 116 hours' duration with natural draft, using air burners. Oil City Boiler Works burner.]

Maximum and minimum values observed during each watch.												
Draft present in inches of water.					Oil.		Water fed per hour and during watch.	Flue gases.				Height of barometer at mid-watch.
Furnace.	Combustion chamber.	Tube chamber.	Above tubes, below drums.	Base of stack.	Burned per hour and during watch.	Total weight burned.		Time sample was drawn.	CO_2.	O.	CO.	
					Lbs.	*Lbs.*	*Lbs.*	*p. m.*	*P. ct.*	*P. ct.*	*P. ct.*	*Ins.*
—0. 25	—0. 20	—0. 30	—0. 40	—0. 40	818	......	9, 942	1. 45	7. 4	10. 8	0. 1	29. 99
— . 15	— . 20	— . 20	— . 35	— . 40	3, 270	3, 270	39, 769	2	7. 4	10. 7	0	
— . 20	— . 20	— . 30	— . 40	— . 45	864	......	10, 580					29. 82
— . 15	— . 20	— . 25	— . 30	— . 40	6, 912	10, 182	84, 638					
— . 20	— . 25	— . 33	— . 40	— . 50	826	......	10, 133	*a. m.*				30. 03
— . 13	— . 20	— . 28	— . 33	— . 45	6, 608	16, 790	81, 064					
— . 18	— . 25	— . 30	— . 38	— . 48	847	......	10, 520	8. 45	7. 5	10. 3	. 1	30. 00
— . 15	— . 20	— . 27	— . 35	— . 40	6, 773	23, 563	84, 156	9. 15	7. 6	10. 2	0	
— . 18	— . 25	— . 28	— . 35	— . 46	847	......	10, 518					29. 76
— . 17	— . 22	— . 25	— . 33	— . 40	6, 772	30, 335	84, 148					
— . 20	— . 28	— . 30	— . 40	— . 50	872	......	10, 657					29. 87
— . 15	— . 25	— . 25	— . 33	— . 45	6, 974	37, 309	85, 253					
— . 18	— . 28	— . 35	— . 40	— . 50	848	......	10, 437	9. 30	7. 8	10. 1	0	29. 86
— . 13	— . 22	— . 30	— . 35	— . 45	6, 780	44, 089	83, 495	10	7. 8	10	0	
— . 20	— . 28	— . 35	— . 45	— . 50	838	......	10, 256					29. 69
— . 13	— . 23	— . 28	— . 40	— . 48	6, 704	50, 793	82, 044					
— . 20	— . 25	— . 35	— . 45	— . 50	837	......	10, 251					29. 89
— . 18	— . 23	— . 30	— . 40	— . 50	6, 694	57, 487	82, 007					
— . 18	— . 25	— . 33	— . 43	— . 50	836	......	10, 414	10. 30	7. 9	10. 8	. 3	29. 98
— . 15	— . 23	— . 30	— . 40	— . 48	6, 687	64, 174	83, 315	10. 45	7. 8	10. 1	. 1	
— . 20	— . 25	— . 33	— . 40	— . 48	820	......	10, 140					29. 77
— . 15	— . 23	— . 28	— . 35	— . 48	6, 559	70, 733	81, 119					
— . 20	— . 25	— . 35	— . 45	— . 50	819	......	10, 151					29. 89
— . 20	— . 23	— . 28	— . 40	— . 48	6, 551	77, 284	81, 204					
— . 20	— . 25	— . 33	— . 40	— . 50	816	......	10, 127	9. 30	7. 8	9. 7	0	29. 91
— . 18	— . 20	— . 25	— . 35	— . 45	6, 529	83, 813	81, 013	10	7. 8	9. 8	0	
— . 19	— . 22	— . 31	— . 40	— . 48	809	......	10, 145					29. 81
— . 15	— . 20	— . 28	— . 35	— . 41	6, 452	90, 265	81, 163					
— . 18	— . 22	— . 30	— . 40	— . 43	782	......	9, 762					30. 05
— . 15	— . 20	— . 30	— . 35	— . 42	6, 252	96, 517	78, 094					
— . 17	— . 23	— . 30	— . 36	— . 46	832	......	10, 280	(*a*)	7. 68	10. 25	. 06	29. 89

a Average.

State of weather: August 4, clear; August 5, 12 p. m. to 8 a. m., clear; 8 a. m. to 12 p. m., cloudy; thunderstorm. August 6, 12 p. m. to 8 a. m., rain; 8 a. m. to 12 p. m., thunderstorm. August 7, clear and cool. August 8, clear, then partly cloudy. August 9, partly cloudy.

No. 7.—*Test of oil fuel in a Hohenstein water-tube marine boiler, August 15, 1902.*

[Six hours' duration with natural draft, but with the Root blower working at its maximum capacity. Oil City Boiler Works burner.]

Time.	Steam pressure by gauge.	Temperature of feed water.	Calorimeter.			Height of water in gauge glass.	Draft pressures in inches of water.				
			Higher temperature.	Lower temperature.	Quality of steam.		Furnace.	Combustion chamber.	Tube chamber.	Above tubes, below drums.	Base of stack.
	Lbs.	° *F.*	° *F.*	° *F.*		*Ins.*					
10.15 a. m.	265	116	390	305	0.989	1.5	—0.10	—0.15	—0.20	—0.35	—0.50
10.30 a. m.	265	114	390	312	.993	2	— .10	— .15	— .20	— .35	— .53
10.45 a. m.	273	114	392	312	.992	3	— .10	— .13	— .18	— .35	— .52
11 a. m ...	274	120	392	314	.993	3	— .10	— .12	— .20	— .35	— .53
11.15 a. m.	274	120	392	314	.993	2.5	— .10	— .13	— .20	— .35	— .52
11.30 a. m.	274	119	392	314	.993	2.5	— .10	— .12	— .20	— .35	— .53
11.45 a. m.	274	122	391	314	.993	2	— .10	— .13	— .20	— .35	— .52
12 m	274	120	390	314	.994	2	— .10	— .12	— .20	— .35	— .53
12.15 p. m.	275	122	390	316	.995	3	0	— .13	— .20	— .35	— .52
12.30 p. m.	275	122	390	316	.995	2.5	0	— .12	— .20	— .35	— .53
12.45 p. m.	272	118	390	316	.995	2.5	— .10	— .13	— .20	— .35	— .52
1 p. m	275	120	390	316	.995	2	— .10	— .12	— .20	— .35	— .53
1.15 p. m..	275	118	390	316	.995	2.5	— .08	— .10	— .20	— .35	— .52
1.30 p. m..	275	120	390	316	.995	3	— .10	— .10	— .20	— .35	— .53
1.45 p. m..	275	121	390	316	.995	3	— .10	— .13	— .23	— .38	— .55
2 p. m	275	120	390	316	.995	2.5	— .10	— .12	— .20	— .37	— .55
2.15 p. m..	275	122	390	316	.995	2.5	— .10	— .13	— .20	— .38	— .55
2.30 p. m..	276	122	390	316	.995	2.5	— .10	— .12	— .20	— .37	— .58
2.45 p. m..	275	120	390	316	.995	2.5	— .10	— .13	— .23	— .38	— .57
3 p. m	275	120	390	318	.996	3	— .10	— .12	— .22	— .37	— .58
3.15 p. m..	276	120	390	320	.997	3.5	— .10	— .13	— .23	— .38	— .57
3.30 p. m..	276	120	390	320	.997	2.5	— .10	— .15	— .22	— .37	— .58
3.45 p. m..	276	122	390	320	.997	2.5	— .10	— .15	— .23	— .38	— .57
4 p. m	276	120	390	320	.997	2.5	— .10	— .15	— .22	— .37	— .58
4.15 p. m..	276	120	390	320	.997	2.5	— .10	— .15	— .23	— .38	— .57
Average ..	274	119.7	......	......	.995	....	— .09	— .13	— .21	— .36	— .54

State of weather, thin fleecy clouds.
Barometer at noon, 30.10 inches.
Kind of fuel, Beaumont oil.
Revolutions of Root blower, 246.7 per minute.
Draft openings into furnace, 642 square inches.
The smoke varied from 0 to 1, averaging about 0.4 by Ringelmann charts.

No. 7.—*Test of oil fuel in a Hohenstein water-tube marine boiler, August 15, 1902.*

[Six hours' duration with natural draft, but with the Root blower working at its maximum capacity. Oil City Boiler Works burner.]

Time.	Air from Root blower, pressure per square inch.	Temperature.				Flue gases.			Oil burned per hour.	Water fed per hour.
		Outside air.	Air in fire room.	Gases at base of stack.	Air from Root blower.	CO_2.	O.	CO.		
	Lbs.	° *F.*	° *F.*	° *F.*	° *F.*	*P. ct.*	*P. ct.*	*P. ct.*	*Lbs.*	*Lbs.*
10.15 a. m	4.63	73	95	......	124	......	......	......	0	0
10.30 a. m	4.63	73	98	710	132	10.2	6.9	0.1	......	......
10.45 a. m	4.63	74	100	......	138	......	......	......	......	......
11 a. m	4.63	74	101	710	143	9.9	6.6	.5	......	......
11.15 a. m	4.63	75	104	......	148	......	......	......	1,501	17,226
11.30 a. m	4.63	75	108	730	149	10	6.6	.2	......	......
11.45 a. m	4.63	76	111	......	154	......	......	......	......	......
12 m	4.63	77	110	725	157	10.2	6.4	.4	......	......
12.15 p. m	4.63	77	114	......	158	......	......	......	1,477	17,383
12.30 p. m	4.63	78	110	725	160	9.7	6.6	.5	......	......
12.45 p. m	4.63	78	113	......	160	......	......	......	......	......
1 p. m	4.63	80	120	740	161	10	6.8	.2	......	......
1.15 p. m	4.63	79	120	......	160	......	......	......	1,465	17,002
1.30 p. m	4.63	79	122	745	166	10.3	6.6	.1	......	......
1.45 p. m	4.63	80	126	......	168	......	......	......	......	......
2 p. m	4.63	80	128	748	170	9.8	7.1	.1	......	......
2.15 p. m	4.63	78	130	......	170	......	......	......	1,566	17,639
2.30 p. m	4.63	80	134	760	172	9.8	7	.5	......	......
2.45 p. m	4.75	80	135	......	173	......	......	......	......	......
3 p. m	4.75	79	142	777	174	10.3	6.4	.3	......	......
3.15 p. m	4.75	79	138	......	175	......	......	......	1,558	18,073
3.30 p. m	4.75	79	138	790	178	10.7	6.3	.2	......	......
3.45 p. m	4.75	79	135	......	176	......	......	......	......	......
4 p. m	4.75	79	136	800	178	10.4	6.4	.2	......	......
4.15 p. m	4.75	79	133	......	178	......	......	......	1,522	17,673
Average	4.66	77.6	120	747	161	10.1	6.64	.275	1,515	17,499

Temperature near middle of furnace, 2,200° F.
Temperature of gases just after turning edge of first baffle, 2,090° F.
Toward the close of the test the temperature over the platform in the fireroom reached 220° F., a serious objection to this method of forcing combustion.
Total pounds oil burned, 9,089.
Total pounds water fed, 104,996.

No. 8.—*Test of oil fuel in a Hohenstein water-tube marine boiler, August 20, 1902.*

[Three hours' duration with forced draft, using air burners. Oil City Boiler Works burner.]

Time.	Steam pressure by gauge.	Temperature of feed water.	Calorimeter.			Height of water in gauge glass.	Draft pressures in inches of water.				
			Higher temperature.	Lower temperature.	Quality of steam.		Fireroom.	Furnace.	Combustion chamber.	Tube chamber.	Base of stack.
	Lbs.	°*F.*	°*F.*	°*F.*		*Ins.*					
11 a. m ...	277	120	384	298	0.987	1.5	Estimated from revolutions of fan.	3.2	2.3	1.8	—0.4
11.15 a. m .	278	120	384	298	.987	2		3.2	2.3	1.8	— .5
11.30 a. m.	278	120	384	298	.987	2.5		3.3	2.3	1.8	— .5
11.45 a. m.	278	128	385	298	.986	2		3.4	2.3	1.8	— .5
12 m	277	120	385	302	.989	2.5		3.5	2.3	1.8	— .5
12.15 p. m.	278	118	386	306	.991	2.5		3.5	2.3	1.9	— .5
12.30 p. m.	277	118	386	306	.991	2		3.5	2.3	1.9	— .5
12.45 p. m.	277	118	386	306	.991	3		3.5	2.3	1.9	— .5
1 p m	277	116	386	306	.991	2.5		3.5	2.3	1.9	— .6
1.15 p. m..	278	118	386	302	.988	2		3.5	2.3	1.9	— .6
1.30 p. m..	278	118	386	298	.986	2		3.5	2.3	1.9	— .6
1.45 p. m..	277	114	386	302	.988	3		3.5	2.3	1.9	— .6
2 p. m	278	115	386	302	.988	2.5		3.5	2.3	1.9	— .6
Average ..	277.5	119	......	......	.988	....	3.75	3.4	2.3	1.86	— .53

State of weather, smoky; occasional clouds.
Barometer at noon, 30.08 inches.
Kind of fuel, Beaumont oil.
Revolutions of fan blower, 506.
Revolutions of Root blower, 248.
Draft openings into furnace, 642 square inches.

No. 8.—*Test of oil fuel in a Hohenstein water-tube marine boiler, August 20, 1902.*

[Three hours' duration with forced draft, using air burners. Oil City Boiler Works burner.]

Time.	Air from Root blower, pressure per square inch.	Temperature.				Flue gases.			Oil burned per hour.	Water fed per hour.
		Outside air.	Air in fireroom.	Gases at base of stack.	Air from Root blower.	CO_2.	O.	CO.		
	Lbs.	°*F.*	°*F.*	°*F.*	°*F.*	*P. ct.*	*P. ct.*	*P. ct.*	*Lbs.*	*Lbs.*
11 a. m.	4.68	80	110	......	132	......	......	......	0	0
11.15 a. m.	4.68	80	112	918	133	7.2	10.5	0.3	......	......
11.30 a. m.	4.68	80	112	......	133	......	......	......	......	......
11.45 a. m.	4.68	81	113	927	134	6.9	11.1	.3	......	......
12 m.	4.68	81	113	......	134	......	......	......	3,143	29,672
12.15 p. m.	4.68	81	114	1,200	136	8.6	8.3	.2	......	......
12.30 p. m.	4.68	82	115	......	136	......	......	......	......	......
12.45 p. m.	4.68	82	116	1,027	136	8.1	9.4	0.0	......	......
1 p. m.	4.68	82	117	......	138	......	......	......	3,454	31,469
1.15 p. m.	4.68	83	117	1,015	138	8.2	9.5	.3	......	......
1.30 p. m.	4.68	83	117	......	138	......	......	......	......	......
1.45 p. m.	4.68	83	117	1,015	138	8.2	9.2	.2	......	......
2 p. m.	4.68	84	118	......	138	......	......	......	3,312	32,244
Average	4.68	82	115	1,017	136	7.87	9.66	.22	3,303	31,128

Very thick black smoke throughout the test.
From 12.15 p. m. to end of test, continuous flaming in stack.
After test was over, 42 pounds of carbon were removed from furnace.
Total pounds oil burned, 9,909.
Total pounds water fed, 93,385.

No. 9.—*Test of oil fuel in a Hohenstein water-tube marine boiler, September 12, 1902.*

[Six hours' duration with natural draft, using "Hayes" steam burners.]

Time.	Steam pressure by gauge.	Temperature of feed water.	Calorimeter.			Height of water in gauge glass.	Temperature.				Pressure of steam used in spraying oil.
			Higher temperature.	Lower temperature.	Quality of steam.		Outside air.	Air in fireroom.	Oil in weighing tank.	Gases at base of stack.	
	Lbs.	° *F.*	° *F.*	° *F.*		*Ins.*	° *F.*	° *F.*	° *F.*	° *F.*	*Lbs.*
1.30 p. m..	275	122	388	302	0.988	2.5	76	96	......	460	30
1.45 p. m..	275	120	386	304	.989	2.75	77	95	......	......	30
2 p. m	275	119	386	306	.991	2.75	77	98	72.5	440	32
2.15 p. m..	275	120	386	308	.992	2.5	77	98	......	......	32
2.30 p. m..	274	134	386	308	.992	2.5	78	98	......	......	32
2.45 p. m..	275	125	386	308	.992	2.5	79	99	......	......	33
3 p. m	275	130	386	308	.992	2.75	79	100	72	......	33
3.15 p. m..	275	137	386	308	.992	2.75	77	99	......	......	32
3.30 p. m..	275	140	386	308	.992	2.5	78	98	......	......	32
3.45 p. m..	275	138	386	308	.992	2.75	77	99	......	......	32
4 p. m	275	137	386	303	.989	2.75	77	99	72	......	30
4.15 p. m..	275	130	386	303	.989	3	77	100	......	......	31
4.30 p. m..	275	136	386	303	.989	2.5	78	100	......	......	32
4.45 p. m..	276	124	386	306	.991	2.5	76	99	......	450	32
5 p. m	275	118	384	306	.991	2.5	74	100	72	......	32
5.15 p. m..	275	130	386	308	.992	2.75	74	99	......	445	32
5.30 p. m..	275	120	386	308	.992	2.5	74	99	......	......	32
5.45 p. m..	275	130	386	306	.991	2.5	74	98	......	......	32
6 p. m	275	130	386	306	.991	2.5	73	99	72	......	32
6.15 p. m..	275	130	384	306	.991	2.5	72	98	......	......	32
6.30 p. m..	275	120	384	306	.991	2.5	70	97	......	......	32
6.45 p. m..	275	122	384	306	.991	2.5	70	96	......	......	32
7 p. m	275	122	384	306	.991	2.5	70	94	71	......	32
7.15 p. m..	275	124	384	306	.991	2.5	70	94	......	......	32
7.30 p. m..	275	120	386	306	.991	2.5	68	92	......	......	32
Average ..	275	127	......	......	.991	......	75	98	72	449	32

State of weather, partly cloudy.
Barometer at noon, 30.16 inches.
Kind of fuel, Beaumont oil.
Draft opening into furnace, 180 square inches.
Pressure in oil-pipe air chamber, 20.3 pounds.
Temperature over fireroom platform, average, 165° F., maximum, 170° F.

No. 9.—*Test of oil fuel in a Hohenstein water-tube marine boiler, September 12, 1902.*

[Six hours' duration with natural draft, using "Hayes" steam burners.]

Time.	Draft pressures in inches of water.				Flue gases.			Oil burned per hour.	Steam used by burners per hour.	Feed water per hour.
	Furnace.	Combustion chamber.	Tube chamber.	Base of stack.	CO₂.	O.	CO.			
					P. ct.	*P. ct.*	*P. ct.*	*Lbs.*	*Lbs.*	*Lbs.*
1.30 p. m..	—0.20	—0.20	0.20	0.32	5.6	12.7	0.2	0	0	0
1.45 p. m..	— .20	— .20	— .20	.38						
2 p. m.....	— .18	— .20	— .20	— .35	4.8	13.7	.3			
2.15 p. m..	— .19	— .20	— .22	— .33						
2.30 p. m..	.20	— .20	— .20	— .32				572	456	6,702
2.45 p. m..	— .18	— .20	— .22	— .38						
3 p. m.....	— .21	— .20	— .20	— .38						
3.15 p. m..	— .20	— .20	— .20	— .38						
3.30 p. m..	— .20	— .20	— .20	— .38				601	402	7,311
3.45 p. m..	— .20	— .20	— .20	— .35						
4 p. m.....	— .20	— .20	— .20	— .35						
4.15 p. m..	— .20	.20	— .20	— .35						
4.30 p. m..	— .20	— .20	— .20	— .38				602	553	7,241
4.45 p. m..	— .20	— .20	— .20	— .40	6	12.8	.3			
5 p. m.....	— .20	— .20	— .20	— .38						
5.15 p. m..	— .20	— .20	— .20	— .38	5.6	13	.3			
5.30 p. m..	— .21	— .21	— .21	— .40				590	459	7,480
5.45 p. m..	— .22	— .21	— .21	— .40						
6 p. m.....	— .22	— .21	— .21	— .40						
6.15 p. m..	— .22	— .21	— .21	— .40						
6.30 p. m..	— .22	— .21	— .21	— .40				639	295	7,691
6.45 p. m..	— .22	— .21	— .21	— .41						
7 p. m.....	— .22	— .21	— .21	— .41						
7.15 p. m..	— .22	— .21	— .21	— .41						
7.30 p. m..	— .22	— .21	— .21	— .41				596	459	7,336
Average...	— .205	— .204	— .205	— .38	5.5	13.05	.27	600	421	7,294

10.30 a. m. Started fires. The boilers were under steam yesterday and the water is already quite warm.

12.30 to 1.30 p. m. Data taken during this period shows about the same evaporative capacity as during the succeeding six hours. The smoke ranged from ¼ to 1. Average ¾, by Ringelmann charts. A few ounces of carbon was deposited near the right-hand burner orifice. The burners made comparatively little noise, probably not more than a quarter as much as the compressed-air burners used in the preceding eight tests; but on the other hand the flames were longer, reaching well into the tube chamber.

Total pounds oil burned, 3,600.
Total pounds steam used by burners, 2,524.
Total pounds water fed, 43,761.

No. 10.—*Test of oil fuel in a Hohenstein water-tube marine boiler, September 19, 1902.*

[Eight hours' duration with natural draft, using steam burners. Oil City Boiler Works burner.]

Time.	Steam pressure by gauge.	Temperature of feed water.	Calorimeter.			Height of water in gauge glass.	Temperature.				Pressure of steam used in spraying oil.
			Higher temperature.	Lower temperature.	Quality of steam.		Outside air.	Air in fireroom.	Oil in weighing tank.	Gases at base of stack.	
	Lbs.	° *F.*	° *F.*	° *F.*		*Ins.*	° *F.*	° *F.*	° *F.*	° *F.*	*Lbs.*
10.30 a. m.	275	118	380	308	0.994	2.75	62	90	......	......	28
10.45 a. m.	275	120	380	308	.994	2.75	63	91	......	600	29
11 a. m ...	275	118	380	308	.994	2.75	64	90	68	......	30
11.15 a. m.	275	118	380	308	.994	2.50	64	90	......	......	30
11.30 a. m.	275	115	380	308	.994	2.50	66	91	......	......	30
11.45 a. m.	275	118	380	309	.995	2.50	66	92	......	605	29
12 m......	275	116	380	310	.995	2.50	67	99	68	......	30
12.15 p. m.	275	115	380	310	.995	3	67	99	......	......	30
12.30 p. m.	275	118	382	310	.995	2.50	68	100	......	......	31
12.45 p. m.	275	110	380	310	.995	2.50	68	101	......	600	30
1 p. m	275	112	380	310	.995	2.50	69	100	68	......	30
1.15 p. m..	275	118	380	310	.995	2.50	70	100	......	......	30
1.30 p. m..	275	120	380	310	.995	2.50	71	100	......	......	30
1.45 p. m..	275	120	384	310	.994	3	71	95	......	605	30
2 p m.....	275	120	384	310	.994	3	71	98	68	......	30
2.15 p. m..	275	118	384	310	.994	3	70	98	......	......	30
2.30 p. m..	270	118	384	310	.994	2.50	70	96	......	......	30
2.45 p. m..	275	118	384	310	.994	2.50	70	96	......	580	28
3 p. m	275	120	384	310	.994	2.50	70	94	68	......	28
3.15 p. m..	275	122	384	310	.994	2.50	71	100	......	......	28
3.30 p. m..	275	120	384	310	.994	2.50	71	100	......	......	28
3.45 p. m..	275	120	384	310	.994	2.50	70	98	......	575	28
4 p. m	275	122	384	310	.994	3	70	94	68	......	28
4.15 p. m..	275	118	384	310	.994	2.50	70	98	......	......	30
4.30 p. m..	274	118	384	310	.994	2.50	70	102	......	......	30
4.45 p. m..	274	118	380	310	.995	2.50	70	110	......	595	32
5 p. m	275	118	380	310	.995	2.50	70	106	68	......	32
5.15 p. m..	275	120	380	310	.995	2.50	70	104	......	......	32
5.30 p. m..	274	120	380	310	.995	2.50	70	104	......	......	32
5.45 p. m..	274	120	380	310	.995	2.50	70	100	......	610	32
6 p. m	274	120	380	310	.995	2.50	70	100	69	......	32
6.15 p. m..	274	118	380	310	.995	2.50	70	104	......	......	31
6.30 p. m..	275	120	360	308	1.001	2.75	70	99	......	......	29
Average ..	274.6	118.3	......	......	.995	......	69	98	68.1	596	29.9

State of weather, thin clouds.
Barometer at noon, 30.20 inches.
Kind of fuel, Beaumont oil.
Draft opening into furnace, 500 square inches.
Pressure in oil-pipe air chamber, 20 pounds.
Temperature over fireroom platform, average 177° F., maximum 184° F.
Temperature of superheated steam for burners, 444.4° F.

No. 10.—*Test of oil fuel in a Hohenstein water-tube marine boiler, September 19, 1902.*

[Eight hours' duration with natural draft, using steam burners. Oil City Boiler Works burner.]

Time.	Draft pressures, in inches of water.				Flue gases.			Oil burned per hour.	Steam used by burners per hour.	Feed water per hour.
	Furnace.	Combustion chamber.	Tube chamber.	Base of stack.	CO₂.	O.	CO.			
					P. ct.	*P. ct.*	*P. ct.*	*Lbs.*	*Lbs.*	*Lbs.*
10.30 a. m.	−0.20	−0.15	−0.20	−0.60				0	0	0
10.45 a. m.	— .18	— .18	— .20	— .60	7	10.6	0			
11 a. m.	— .20	— .20	— .20	— .60						
11.15 a. m.	— .20	— .20	— .30	— .60						
11.30 a. m.	— .20	— .20	— .30	— .60				983	475	11,181
11.45 a. m.	— .20	— .20	— .30	— .60	7.1	11.1	0			
12 m.	— .20	— .20	— .30	— .60						
12.15 p. m.	— .20	— .20	— .30	— .60						
12.30 p. m.	— .20	— .20	— .30	— .60				968	365	11,143
12.45 p. m.	— .20	— .20	— .30	— .60	7	11.2	.1			
1 p. m.	— .20	— .20	— .30	— .60						
1.15 p. m.	— .20	— .20	— .30	— .60						
1.30 p. m.	— .20	— .20	— .30	— .60				934	423	11,222
1.45 p. m.	— .20	— .20	— .30	— .60	7	11.1	0			
2 p. m.	— .20	— .20	— .30	— .60						
2.15 p. m.	— .20	— .20	— .30	— .60						
2.30 p. m.	— .20	— .20	— .30	— .60				915	326	10,551
2.45 p. m.	— .20	— .20	— .30	— .60	6.6	11.2	0			
3 p. m.	— .20	— .20	— .30	— .60						
3.15 p. m.	— .20	— .20	— .30	— .60						
3.30 p. m.	— .20	— .20	— .30	— .60				851	399	10,287
3.45 p. m.	— .20	— .20	— .30	— .60	6.6	11.8	0			
4 p. m.	— .20	— .20	— .30	— .60						
4.15 p. m.	— .20	— .20	— .30	— .60						
4.30 p. m.	— .20	— .20	— .30	— .55				826	479	9,733
4.45 p. m.	— .22	— .22	— .25	— .60	7.4	10.8	0			
5 p. m.	— .22	— .22	— .25	— .60						
5.15 p. m.	— .22	— .22	— .25	— .60						
5.30 p. m.	— .22	— .22	— .25	— .60				970	452	11,071
5.45 p. m.	— .21	— .21	— .25	— .58	7.2	10.6	0			
6 p. m.	— .21	— .20	— .25	— .58						
6.15 p. m.	— .20	— .20	— .28	— .58						
6.30 p. m.	— .20	— .20	— .28	— .58				913	493	10,603
Average	— .202	— .201	— .281	— .596	6.99	11.05	.013	920	427	10,724

The angular setting of the side burners is changed so as to direct their flames more toward the center of the furnace. Heretofore the side walls of the furnace have absorbed an undue amount of heat as shown by their glow after extinguishing the burners.

Curved sheet-iron deflectors have been placed in what were formerly the ash pit openings, so as to direct the entering air upward at an angle against the flames.

The smoke averages about ¼, the maximum being ½, by Ringelmann charts.

A disk of carbon 9 inches in diameter was deposited on the back wall opposite the center burners.

The burners make much less noise than those made by the same builders using air.

Total pounds oil burned, 7,360.

Total pounds steam used by burners, 3,412.

Total pounds water fed, 85,791.

No. 11.—*Test of oil fuel in a Hohenstein water-tube marine boiler, September 20, 1902.*

[Eight hours' duration with natural draft, using steam burners. Oil City Boiler Works burner.]

Time.	Steam pressure by gauge.	Temperature of feed water.	Calorimeter.			Height of water in gauge glass.	Temperature.				Pressure of steam used in spraying oil.
			Higher temperature.	Lower temperature.	Quality of steam.		Outside air.	Air in fireroom.	Oil in weighing tank.	Gases at base of stack.	
	Lbs.	° *F.*	° *F.*	° *F.*		*Ins.*	° *F.*	° *F.*	° *F.*	° *F.*	*Lbs.*
9 a. m.	270	118	380	306	0.993	3	66	93	......	......	60
9.15 a. m.	276	118	384	308	.993	3	70	94	......	......	60
9.30 a. m.	271	120	380	308	.994	3	72	96	68	635	60
9.45 a. m.	273	120	382	308	.993	3	74	98	......	......	60
10 a. m.	269	120	380	308	.994	2	76	100	......	......	62
10.15 a. m.	273	120	384	310	.994	2.5	78	100	......	......	62
10.30 a. m.	277	118	384	310	.994	2.5	80	104	68	640	62
10.45 a. m.	277	118	384	310	.994	2.5	80	106	......	......	61
11 a. m.	276	120	384	310	.994	2.5	80	106	......	......	61
11.15 a. m.	277	120	380	310	.995	2.5	80	106	......	......	62
11.30 a. m.	275	118	380	310	.995	2.5	80	104	68	645	62
11.45 a. m.	276	120	384	310	.994	2.5	80	106	......	......	62
12 m.	276	120	384	310	.994	2.5	80	104	......	......	62
12.15 p. m.	273	120	380	310	.995	2.5	80	106	......	......	64
12.30 p. m.	276	120	380	310	.995	2.5	80	106	68	630	65
12.45 p. m.	277	122	380	310	.995	2.5	80	106	......	......	64
1 p. m	277	124	382	310	.994	2.5	80	108	......	......	62
1.15 p. m.	275	120	383	310	.994	2.5	78	108	......	......	62
1.30 p. m.	276	122	383	310	.994	2.5	76	110	68	620	61
1.45 p. m.	278	122	383	310	.994	2.5	76	110	......	......	61
2 p. m	274	124	383	310	.994	2.5	76	110	......	......	61
2.15 p. m.	275	122	383	310	.994	3	76	108	......	......	60
2.30 p. m.	275	122	380	310	.995	2.75	76	108	68	615	60
2.45 p. m.	277	122	380	310	.995	2.75	78	108	......	......	60
3 p. m	275	120	380	310	.995	3	78	108	......	......	60
3.15 p. m.	278	120	380	310	.995	2.5	78	98	......	......	60
3.30 p. m.	277	120	380	310	.995	2.5	78	108	68	620	60
3.45 p. m.	277	120	380	310	.995	2.5	78	110	......	......	60
4 p. m	273	120	380	310	.995	2.5	78	110	......	......	60
4.15 p. m.	277	120	380	310	.995	2.5	78	112	......	......	61
4.30 p. m.	274	118	380	310	.995	2.5	78	112	68	620	62
4.45 p. m.	276	120	380	310	.995	2.5	78	111	......	......	62
5 p. m	276	118	380	310	.995	3	78	110	......	......	62
Average	275.2	120.2	......	......	.994	......	77	106	68	628	61.4

State of weather, thin clouds.
Barometer at noon, 30.18 inches.
Kind of fuel, Beaumont oil.
Draft opening into furnace, 500 square inches.
Pressure in oil-pipe air chamber, 30 pounds.
Temperature over fireroom platform, average 182° F., maximum 188° F.
Temperature of superheated steam for burners, 408.2° F.

No. 11.—*Test of oil fuel in a Hohenstein water-tube marine boiler, September 20, 1902.*

[Eight hours' duration with natural draft, using steam burners. Oil City Boiler Works burner.]

Time	Draft pressures, in inches of water.				Flue gases.			Oil burned per hour.	Steam used by burners per hour.	Feed water per hour.
	Furnace.	Combustion chamber.	Tube chamber.	Base of stack.	CO_2.	O.	CO.			
					P. ct.	*P. ct.*	*P. ct.*	*Lbs.*	*Lbs.*	*Lbs.*
9 a. m	−0. 14	−0. 20	−0. 27	−0. 53	......	......	......	0	0	0
9.15 a. m...	— .14	— .20	— .27	— .54	......	......	......	......	......	......
9.30 a. m...	— .14	— .20	— .29	— .50	7. 4	10. 6	0. 1	......	......	......
9.45 a. m...	— .14	— .18	— .25	— .52	......	......	......	......	......	......
10 a. m	— .14	— .19	— .26	— .52	......	......	......	1, 040	578	12, 117
10.15 a. m..	— .14	— .19	— .28	— .52	......	......	......	......	......	......
10.30 a. m..	— .14	— .18	— .27	— .52	7. 6	10	.3	......	......	......
10.45 a. m..	— .14	— .19	— .26	— .50	......	......	......	......	......	......
11 a. m	— .14	— .19	— .29	— .52	......	......	......	1, 087	523	12, 391
11.15 a. m..	— .14	— .20	— .28	— .53	......	......	......	......	......	......
11.30 a. m..	— .14	— .20	— .28	— .53	7. 6	10. 8	0	......	......	......
11.45 a. m..	— .14	— .20	— .25	— .53	......	......	......	......	......	......
12 m	— .14	— .20	— .28	— .53	......	......	......	1, 056	526	12, 550
12.15 p. m..	— .14	— .20	— .28	— .53	......	......	......	......	......	......
12.30 p. m..	— .14	— .20	— .28	— .53	......	......	......	......	......	......
12.45 p. m..	— .14	— .20	— .28	— .53	......	......	......	......	......	......
1 p. m	— .14	— .20	— .28	— .53	......	......	......	1, 037	554	12, 072
1.15 p. m...	— .14	— .20	— .28	— .53	......	......	......	......	......	......
1.30 p. m...	— .14	— .20	— .28	— .53	7. 8	10. 2	0	......	......	......
1.45 p. m...	— .14	— .20	— .28	— .53	......	......	......	......	......	......
2 p. m	— .14	— .20	— .28	— .53	......	......	......	1, 022	558	12, 082
2.15 p. m...	— .14	— .20	— .25	— .53	......	......	......	......	......	......
2.30 p. m...	— .14	— .20	— .25	— .53	7. 1	11. 1	.2	......	......	......
2.45 p. m...	— .14	— .20	— .25	— .53	......	......	......	......	......	......
3 p. m	— .14	— .20	— .25	— .53	......	......	......	991	472	11, 771
3.15 p. m...	— .14	— .20	— .27	— .53	......	......	......	......	......	......
3.30 p. m...	— .14	— .20	— .27	— .53	7. 0	11. 2	0	......	......	......
3.45 p. m...	— .14	— .19	— .28	— .54	......	......	......	......	......	......
4 p. m	— .14	— .20	— .28	— .55	......	......	......	1, 013	593	11, 635
4.15 p. m...	— .14	— .20	— .28	— .55	......	......	......	......	......	......
4.30 p. m...	— .14	— .19	— .29	— .54	7. 8	10. 7	0	......	......	......
4.45 p. m...	— .13	— .19	— .28	— .53	......	......	......	......	......	......
5 p. m	— .14	— .20	— .28	— .53	......	......	......	1, 011	448	11, 838
Average ...	— .140	— .197	— .279	— .529	7. 47	10. 66	.086	1, 032	532	12, 057

The angular setting of the burners and the deflectors for the entering air are the same as yesterday. (See Test No, 10.)

The smoke averages ¼, the maximum being ½, by Ringelmann charts.

The deposit of carbon was slight and fairly uniform across the back wall of the furnace.

Total pounds oil burned, 8,257.

Total pounds steam used by burners, 4,252.

Total pounds water fed, 96,456.

No. 12.—*Test of oil fuel in a Hohenstein water tube marine boiler, September 22, 1902.*

[Eight hours' duration with natural draft, using steam burners. Oil City Boiler Works burner.]

Time.	Steam pressure by gauge.	Temperature of feed water.	Calorimeter. Higher temperature.	Calorimeter. Lower temperature.	Calorimeter. Quality of steam.	Height of water in gauge glass.	Temperature. Outside air.	Temperature. Air in fire room.	Temperature. Oil in weighing tank.	Temperature. Gases at base of stack.	Pressure of steam used in spraying oil.
	Lbs.	° *F.*	° *F.*	° *F.*		*Ins.*	° *F.*	° *F.*	° *F.*	° *F.*	*Lbs.*
9 a. m	277	118	380	310	0.995	2.5	70	99	......	......	90
9.15 a. m ..	276	120	382	310	.995	2.5	72	102	......	......	90
9.30 a. m ..	276	120	380	310	.995	2.5	72	100	68	665	90
9.45 a. m ..	278	120	380	310	.995	3	72	99	......	......	90
10 a. m....	277	118	380	310	.995	3	73	100	......	......	90
10.15 a. m .	277	120	380	310	.995	2.5	73	100	......	......	92
10.30 a. m .	278	120	380	310	.995	2.5	73	100	68	660	92
10.45 a. m .	278	120	380	310	.995	3	74	100	......	......	91
11 a. m....	277	118	380	310	.995	2.75	74	100	......	......	92
11.15 a. m .	277	120	380	310	.995	3	74	98	......	......	93
11.30 a. m .	275	120	380	310	.995	2.5	74	102	69	655	93
11.45 a. m .	275	120	380	310	.995	2.25	75	104	......	......	93
12 m......	275	120	380	310	.995	2.75	76	104	......	......	93
12.15 p. m .	276	118	380	310	.995	2.75	78	102	......	......	90
12.30 p. m .	275	118	380	310	.995	2.5	78	104	68	660	90
12.45 p. m .	278	120	380	310	.995	3	79	106	......	......	92
1 p. m.....	278	120	380	310	.995	2.5	78	104	......	......	91
1.15 p. m ..	275	120	380	310	.995	3	80	104	......	......	91
1.30 p. m ..	275	120	380	310	.995	3	80	104	68	665	90
1.45 p. m ..	276	120	380	310	.995	4	80	105	......	......	90
2 p. m.....	273	120	378	310	.995	2.75	82	104	......	......	90
2.15 p. m ..	275	120	380	310	.995	2.5	82	105	......	......	90
2.30 p. m ..	275	120	380	310	.995	2	82	106	68	650	90
2.45 p. m ..	275	120	380	310	.995	2	82	104	......	......	90
3 p. m.....	273	120	380	310	.995	2.25	80	105	......	......	90
3.15 p. m ..	275	120	380	310	.995	2.5	80	108	......	......	90
3.30 p. m ..	275	118	380	310	.995	2.75	80	106	68	670	90
3.45 p. m ..	273	118	380	310	.995	2.5	80	106	......	......	91
4 p. m.....	275	120	380	310	.995	2.5	80	106	......	......	92
4.15 p. m ..	272	120	380	310	.995	3	80	105	......	......	91
4.30 p. m ..	275	120	380	310	.995	3	80	106	68	660	89
4.45 p. m ..	275	120	380	310	.995	2.5	79	106	......	......	88
5 p. m.....	277	120	380	310	.995	2.5	78	110	......	......	89
Average ..	275.7	119.6	......	......	.995	......	77	103	68.1	661	91

State of weather, partly cloudy.
Barometer at noon, 30.05 inches.
Kind of fuel, Beaumont oil.
Draft opening into furnace, 500 square inches.
Pressure in oil pipe air chamber, 45 pounds.
Temperature over fire-room platform, average 192° F., maximum 200° F.
Total pounds water fed, 105,547.
Total pounds steam used by burners, 5,305.

No. 12.—*Test of oil fuel in a Hohenstein water tube marine boiler, September 22, 1902.*

[Eight hours' duration with natural draft, using steam burners. Oil City Boiler Works burner.]

Time.	Draft pressures, in inches of water.				Flue gases.			Oil burned per hour.	Steam used by burners per hour.	Feed water per hour.
	Furnace.	Combustion chamber.	Tube chamber.	Base of stack.	CO$_2$.	O.	CO.			
					P. ct.	*P. ct.*	*P. ct.*	*Lbs.*	*Lbs.*	*Lbs.*
9 a. m	—0.14	—0.15	—0.22	—0.52				0	0	0
9.15 a. m	— .14	— .13	— .22	— .53						
9.30 a. m	— .14	— .14	— .21	— .53	8.6	9	0.2			
9.45 a. m	— .14	— .13	— .21	— .52						
10 a. m	— .14	— .15	— .21	— .53				1,157	635	13,375
10.15 a. m	— .14	— .17	— .21	— .54						
10.30 a. m	— .14	— .16	— .22	— .53	9	8.7	.3			
10.45 a. m	— .14	— .16	— .21	— .53						
11 a. m	— .14	— .16	— .21	— .53				1,147	740	13,425
11.15 a. m	— .14	— .16	— .21	— .53						
11.30 a. m	— .14	— .16	— .21	— .53	8.5	9.3	.2			
11.45 a. m	— .14	— .16	— .21	— .53						
12 m	— .15	— .16	— .21	— .53				1,115	747	13,109
12.15 p. m	— .15	— .17	— .21	— .53						
12.30 p. m	— .14	— .17	— .21	— .53	8.2	9.5	0			
12.45 p. m	— .14	— .17	— .21	— .53						
1 p. m	— .14	— .17	— .21	— .53				1,112	509	13,112
1.15 p. m	— .14	— .17	— .21	— .53						
1.30 p. m	— .14	— .17	— .21	— .53	8.5	9.5	0			
1.45 p. m	— .14	— .17	— .21	— .53						
2 p. m	— .14	— .17	— .21	— .53				1,125	710	13,433
2.15 p. m	— .14	— .17	— .21	— .53						
2.30 p. m	— .14	— .17	— .21	— .53	7.5	10.1	.2			
2.45 p. m	— .14	— .17	— .21	— .53						
3 p. m	— .14	— .18	— .21	— .53				1,066	821	12,548
3.15 p. m	— .14	— .17	— .21	— .53						
3.30 p. m	— .14	— .17	— .21	— .54	8.6	8.6	0			
3.45 p. m	— .14	— .17	— .21	— .53						
4 p. m	— .14	— .17	— .21	— .53				1,167	538	13,810
4.15 p. m	— .15	— .18	— .21	— .53						
4.30 p. m	— .15	— .18	— .21	— .53	8.6	9.6	.2			
4.45 p. m	— .15	— .17	— .21	— .53						
5 p. m	— .15	— .17	— .21	— .53				1,085	605	12,735
Average	— .142	— .164	— .211	— .530	8.44	9.29	.014	1,122	663	13,193

Temperature of superheated steam for burners, 401° F.
Setting of burners and deflectors unchanged. (See Test No. 10.)
The smoke averages ⅛, the maximum being ¼, by Ringelmann charts.
No increase in the deposit of carbon.
Blew down boiler. Much mud in the water; also considerable soot among the tubes and on the baffles.
Total pounds oil burned, 8,974.

No. 13.—*Test of oil fuel in Hohenstein water-tube marine boiler, September 27, 1902.*

[Eight hours' duration with natural draft, using "Reed" air and steam burners.]

Time.	Steam pressure by gauge.	Temperature of feed water.	Calorimeter.			Height of water in gauge glass.	Temperature.					
			Higher temperature.	Lower temperature.	Quality of steam.		Outside air.	Air in fireroom.	Gases at base of stack.	Air from Root blower.	Superheated steam for burners.	Oil in weighing tank.
	Lbs.	° *F.*	° *F.*	° *F.*		*Ins.*	° *F.*	° *F.*	° *F.*	° *F.*	° *F.*	° *F.*
10 a. m....	275	114	380	310	0.995	2.5	76	95	.....	110	356	.....
10.15 a. m.	275	116	380	310	.995	3	76	95	.....	112	360	.....
10.30 a. m.	275	116	382	312	.996	2.5	78	94	605	112	360	72
10.45 a. m.	283	122	382	312	.996	3	80	92	.....	112	362	.....
11 a. m....	278	126	382	312	.996	3.5	80	97	.....	112	350	.....
11.15 a. m.	279	122	382	312	.996	3.25	82	98	.....	111	352	.....
11.30 a. m.	276	130	378	312	.997	2.5	82	96	600	112	352	72
11.45 a. m.	279	128	380	312	.996	3.25	78	102	.....	112	352	.....
12 m......	279	126	380	312	.996	2.5	78	98	.....	112	356	.....
12.15 p. m.	279	118	380	312	.996	3	78	98	.....	113	358	.....
12.30 p. m.	279	120	380	312	.996	2.5	78	98	600	113	358	72
12.45 p. m.	279	120	380	312	.996	2.75	80	100	.....	114	380	.....
1 p. m	279	128	380	312	.996	2.75	80	100	.....	114	380	.....
1.15 p. m..	279	124	380	310	.995	2.75	80	100	.....	114	380	.....
1.30 p. m..	278	120	378	312	.997	2.5	82	100	570	115	386	72
1.45 p. m..	277	120	378	312	.997	2.5	80	99	.....	115	382	.....
2 p. m	277	124	378	312	.997	2.5	82	98	.....	116	380	.....
2.15 p. m..	277	122	376	310	.997	2.5	90	99	.....	116	380	.....
2.30 p. m..	278	120	376	310	.997	2.5	90	100	565	116	380	72
2.45 p. m..	278	120	378	310	.996	2.5	90	102	.....	116	382	.....
3 p. m.....	278	120	378	312	.997	2.75	92	102	.....	116	384	.....
3.15 p. m..	277	120	378	310	.996	2.5	84	103	.....	116	384	.....
3.30 p. m..	279	120	378	310	.996	2.5	82	103	560	116	384	72
3.45 p. m..	278	120	378	310	.996	2.75	80	102	.....	116	386	.....
4 p. m.....	279	124	378	312	.997	2.75	80	104	.....	116	386	.....
4.15 p. m..	279	122	380	310	.995	2.75	80	102	.....	115	388	.....
4.30 p. m..	279	128	380	310	.995	3	79	100	580	115	386	72
4.45 p. m..	278	120	376	310	.997	2.75	78	102	.....	114	382	.....
5 p. m.....	277	126	378	310	.996	2.5	78	104	.....	113	380	.....
5.15 p. m..	279	120	378	310	.996	3	78	99	.....	114	385	.....
5.30 p. m..	279	128	378	310	.996	2.75	76	100	540	114	388	73
5.45 p. m..	279	118	378	310	.996	3	74	98	.....	116	396	.....
6 p. m.....	279	120	378	310	.996	2	74	99	.....	114	398	.....
Average ..	278.2	121.9	.....	.....	.996	.....	80.4	99.4	578	114	375	72.1

State of weather, fair.
Barometer at noon, 29.92 inches.
Kind of fuel, Beaumont oil.
Revolutions of Root blower, 215 per minute.
Draft opening into furnace in square inches, average, 165; maximum, 204; minimum, 114.
Temperature over fireroom platform, maximum, 182° F.; average, 179° F.
Pressure in oil system at air chamber, 20 pounds.
Very little smoke; at times none.
Total pounds feed water, 95,395.
Total pounds steam used by burners, 5,856.
Total pounds oil burned, 7,692.

No. 13.—*Test of oil fuel in Hohenstein water-tube marine boiler, September 27, 1902.*

[Eight hours' duration with natural draft, using "Reed" air and steam burners.]

Time.	Pressures per square inch.		Draft pressure in inches of water.				Flue gases.			Oil burned per hour.	Steam used by burner per hour.	Feed water per hour.
	Air from Root blower.	Steam for burners.	Furnace.	Combustion chamber.	Tube chamber.	Base of stack.	CO$_2$.	O.	CO.			
	Lbs.	*Lbs.*					*P. ct.*	*P. ct.*	*P. ct.*	*Lbs.*	*Lbs.*	*Lbs.*
10 a. m.	1.61	90	—0.15	—0.15	—0.20	—0.45				0	0	0
10.15 a. m.	1.61	93	— .15	— .15	— .20	— .45						
10.30 a. m.	1.61	93	— .15	— .15	— .20	— .45	8.7	8.7	0			
10.45 a. m.	1.58	95	— .15	— .15	— .20	— .45						
11 a. m.	1.61	93	— .15	— .15	— .20	— .45				1,051	967	12,943
11.15 a. m.	1.46	94	— .15	— .15	— .20	— .45						
11.30 a. m.	1.61	95	— .15	— .15	— .20	— .45	7.5	10.3	.2			
11.45 a. m.	1.61	95	— .15	— .15	— .20	— .45						
12 m.	1.46	95	— .15	— .15	— .20	— .45				972	984	11,778
12.15 p. m.	1.61	92	— .15	— .15	— .20	— .45						
12.30 p. m.	1.61	92	— .15	— .15	— .20	— .45	8.0	9.6	0			
12.45 p. m.	1.61	92	— .15	— .15	— .20	— .45						
1 p. m.	1.61	92	— .15	— .15	— .20	— .45				1,006	1,042	12,239
1.15 p. m.	1.61	91	— .15	— .15	— .20	— .45						
1.30 p. m.	1.46	92	— .15	— .15	— .20	— .45	8.2	9.4	0			
1.45 p. m.	1.46	91	— .15	— .15	— .20	— .45						
2 p. m.	1.46	91	— .15	— .15	— .20	— .45				1,002	696	12,078
2.15 p. m.	1.46	90	— .15	— .15	— .20	— .45						
2.30 p. m.	1.46	90	— .15	— .15	— .20	— .45	7.8	9.8	0			
2.45 p. m.	1.46	90	— .15	— .15	— .20	— .45						
3 p. m.	1.46	90	— .15	— .15	— .20	— .45				970	626	11,936
3.15 p. m.	1.46	90	— .15	— .15	— .20	— .45						
3.30 p. m.	1.46	92	— .15	— .15	— .20	— .45	7.4	11	.2			
3.45 p. m.	1.46	91	— .15	— .15	— .20	— .45						
4 p. m.	1.46	90	— .15	— .15	— .20	— .45				920	596	11,348
4.15 p. m.	1.46	91	— .15	— .15	— .20	— .45						
4.30 p. m.	1.46	91	— .15	— .15	— .20	— .45	7	9.2	.2			
4.45 p. m.	1.46	90	— .15	— .15	— .20	— .45						
5 p. m.	1.46	92	— .15	— .15	— .20	— .45				907	490	11,145
5.15 p. m.	1.46	92	— .15	— .15	— .20	— .45						
5.30 p. m.	1.36	92	— .15	— .15	— .20	— .45	7	10.8	0			
5.45 p. m.	1.46	90	— .15	— .15	— .20	— .45						
6 p. m.	1.34	90	— .15	— .15	— .20	— .45				864	455	11,928
Average	1.51	92	— .15	— .15	— .20	— .45	7.70	9.85	.075	962	732	11,924

The front wall of the furnace has been rebuilt and now has openings 8 inches in diameter for the burners. This provides an annular opening for the admission of atmospheric air around each burner.

September 26: A preliminary run of 9 hours was made with a bridge wall built across the furnace 9 inches from the back wall and up to within 9 inches of the lower row of tubes. The wall was hollow and had perforations in front, its object being to introduce heated air at the back of the furnace. The front of the wall was in the form of 4 steps, each 8 inches high. The wall proved to be too high, choking the draft. In preparation for the trial of September 27, the top step was removed; also, to reduce loss by downward radiation of heat, inclined sheets of asbestos were laid on the lowest step of the bridge wall, the sheets extending to the front of the furnace.

September 27: At the end of the test there was a deposit of carbon about 9 inches in diameter on the bridge wall opposite the right burners. The perforations in the bridge wall were partially choked with slag melted out of the brickwork.

No. 14.—*Test of oil fuel in a Hohenstein water-tube marine boiler, September 29, 1902.*

[Eight hours' duration with natural draft, using "Reed" air and steam burners.]

Time.	Steam pressure by gauge.	Temperature of feed water.	Calorimeter.			Height of water in gauge glass.	Temperature.					
			Higher temperature.	Lower temperature.	Quality of steam.		Outside air.	Air in fireroom.	Gases at base of stack.	Air from Root blower.	Super-heated steam for burners.	Oil in weighing tank.
	Lbs.	° *F.*	° *F.*	° *F.*		*Ins.*	° *F.*	° *F.*	° *F.*	° *F.*	° *F.*	° *F.*
9.15 a. m..	279	120	380	312	0.996	2.5	76	98	.....	112	400	....
9.30 a. m..	279	120	380	313	.997	2.5	78	101	685	111	390	74
9.45 a. m..	279	120	376	314	.999	3	79	102	.....	112	404	....
10 a. m....	279	112	380	312	.996	2	80	105	.....	113	410	....
10.15 a. m.	279	122	380	313	.997	2.5	82	106	.....	114	386	....
10.30 a. m.	279	126	380	312	.996	2.5	82	104	645	114	360	74
10.45 a. m.	279	120	380	314	.997	2.75	82	108	.....	114	354	....
11 a. m....	279	120	378	314	.998	2.5	82	108	.....	114	368	....
11.15 a. m.	279	120	380	314	.997	2.5	84	109	.....	115	370	....
11.30 a. m.	279	120	380	314	.998	2.5	86	110	660	115	370	74
11.45 a. m.	279	120	380	314	.997	3	86	111	.....	116	363	....
12 m......	279	120	380	314	.998	2.5	84	110	.....	116	364	....
12.15 p. m.	278	124	376	314	.999	2.5	84	112	.....	117	430	....
12.30 p. m.	279	120	376	314	.999	3	84	110	645	116	456	74
12.45 p. m.	278	124	376	314	.999	2.5	84	111	.....	117	476	....
1 p. m	279	120	376	314	.999	2.5	84	111	.....	118	480	....
1.15 p. m..	279	120	376	314	.999	2.75	85	112	.....	118	484	....
1.30 p. m..	279	124	376	314	.999	2.5	84	114	600	118	476	74
1.45 p. m..	279	124	376	314	.999	2.5	84	113	.....	118	480	....
2 p. m	279	120	376	314	.999	2.5	84	114	.....	119	460	....
2.15 p. m..	279	120	376	314	.999	3	92	114	.....	120	460	....
2.30 p. m..	279	124	376	314	.999	3	90	115	630	120	454	74
2.45 p. m..	279	120	376	314	.999	2.75	90	118	.....	120	450	....
3 p. m	279	120	376	314	.999	2.5	92	118	.....	120	430	....
3.15 p. m..	279	122	376	314	.999	2.5	92	118	.....	120	420	....
3.30 p. m..	278	120	376	314	.999	2	93	114	655	120	420	74
3.45 p. m..	278	120	376	314	.999	2.5	96	116	.....	121	420	....
4 p. m	279	120	378	316	.999	2.25	96	116	.....	122	410	....
4.15 p. m..	279	122	378	316	.999	2.5	92	114	.....	122	380	....
4.30 p. m..	279	120	378	316	.999	2.5	86	116	640	122	390	74
4.45 p. m..	279	120	378	316	.999	3	83	116	.....	122	408	....
5 p. m	279	124	378	316	.999	3	82	116	.....	122	406	....
5.15 p. m..	279	120	378	316	.999	2.5	80	118	.....	122	402	....
Average...	278.9	120.8	.....	.....	.998	.....	85.4	111.5	645	117.5	416	74

State of weather, clear.

Barometer at noon, 29.96 inches.

Kind of fuel, Beaumont oil.

Revolutions of Root blower, 239 per minute, of which 52 were required by burner in auxiliary boiler.

Draft openings into furnace, 664 square inches until 10.30 a. m., then 408 square inches.

Temperature over fireroom platform, maximum 196° F., average 187° F.

Pressure in oil system at air chamber, 20 pounds.

Average smoke, ¼; maximum, ½ by Ringelmann charts.

Total pounds steam used by burners, 4,458.

Total pounds feed water, 112,115.

Pounds of oil burned per hour, 9,216.

No. 14.—*Test of oil fuel in a Hohenstein water-tube marine boiler, September 29, 1902.*

[Eight hours' duration with natural draft, using "Reed" air and steam burners.]

Time.	Pressures per square inch.		Draft pressure in inches of water.				Flue gases.			Oil burned per hour.	Steam used by burners per hour.	Feed water per hour.
	Air from Root blower.	Steam for burners.	Furnace.	Combustion chamber.	Tube chamber.	Base of stack.	CO_2.	O.	CO.			
	Lbs.	*Lbs.*					*P. ct.*	*P. ct.*	*P. ct.*	*Lbs.*	*Lbs.*	*Lbs.*
9.15 a. m.	1.46	90	−0.05	−0.1	−0.2	−0.5	....	....	....	0	0	0
9.30 a. m.	1.46	88	− .05	− .1	− .2	− .5	8.3	9.7	0	....	....	....
9.45 a. m.	1.34	92	− .1	− .1	− .2	− .5	....	....	....	....	....	....
10 a. m.	1.46	93	− .1	− .1	− .2	− .5	....	....	....	....	....	....
10.15 a. m.	1.41	93	− .1	− .1	− .2	− .5	....	....	....	1,143	808	13,572
10.30 a. m.	1.41	92	− .1	− .1	− .2	− .5	8.3	8.5	0	....	....	....
10.45 a. m.	1.46	90	− .1	− .1	− .2	− .5	....	....	....	....	....	....
11 a. m.	1.46	90	− .1	− .1	− .2	− .5	....	....	....	....	....	....
11.15 a. m.	1.46	90	− .1	− .1	− .2	− .5	....	....	....	1,194	670	14,376
11.30 a. m.	1.46	90	− .1	− .1	− .2	− .5	8.6	8.8	0	....	....	....
11.45 a. m.	1.41	90	− .1	− .1	− .2	− .5	....	....	....	....	....	....
12 m.	1.46	90	− .1	− .1	− .2	− .5	....	....	....	....	....	....
12.15 p. m.	1.21	93	− .1	− .1	− .2	− .5	....	....	....	1,133	684	13,971
12.30 p. m.	1.21	94	− .1	− .1	− .2	− .5	8.5	9.4	.1	....	....	....
12.45 p. m.	1.21	92	− .1	− .1	− .2	− .5	....	....	....	....	....	....
1 p. m	1.21	86	− .1	− .1	− .2	− .5	....	....	....	....	....	....
1.15 p. m.	1.21	88	− .1	− .1	− .2	− .5	....	....	....	1,145	281	14,108
1.30 p. m.	1.46	88	− .1	− .1	− .2	− .5	8.4	9	0	....	....	....
1.45 p. m.	1.46	87	− .1	− .1	− .2	− .5	....	....	....	....	....	....
2 p. m	1.46	87	− .1	− .1	− .2	− .5	....	....	....	....	....	....
2.15 p. m.	1.46	87	− .1	− .1	− .2	− .5	....	....	....	1,157	370	14,192
2.30 p. m.	1.46	87	− .1	− .1	− .2	− .5	8.4	9.4	.2	....	....	....
2.45 p. m.	1.21	88	− .1	− .1	− .2	− .5	....	....	....	....	....	....
3 p. m	1.21	86	− .1	− .1	− .2	− .5	....	....	....	....	....	....
3.15 p. m.	1.21	86	− .1	− .1	− .2	− .5	....	....	....	1,133	332	13,640
3.30 p. m.	1.21	87	− .1	− .1	− .2	− .5	8.6	8.9	0	....	....	....
3.45 p. m.	1.21	86	− .1	− .1	− .2	− .5	....	....	....	....	....	....
4 p. m	1.34	88	− .1	− .1	− .2	− .5	....	....	....	....	....	....
4.15 p. m.	1.46	90	− .1	− .1	− .2	− .5	....	....	....	1,196	633	14,284
4.30 p. m.	1.46	90	− .1	− .1	− .2	− .5	9.1	8.6	.1	....	....	....
4.45 p. m.	1.46	90	− .1	.1	− .2	− .5	....	....	....	....	....	....
5 p. m	1.46	91	− .1	− .1	− .2	− .5	....	....	....	....	....	....
5.15 p. m.	1.34	90	− .1	− .1	− .2	− .5	....	....	....	1,115	680	13,972
Average	1.37	89	− .097	− .10	− .20	− .50	8.53	9.04	.05	1,152	557	14,014

Before beginning this test another step of 8 inches was removed from the top of the bridge wall, and brick uptakes were built in the furnace so as to lead the air from the old ashpit openings vertically upward to the burners.

During the test the quantity of steam used in the burners was the least permissible—i. e., a further reduction would result in the production of smoke.

At the end of the test there was a deposit of carbon 10 inches in diameter on the bridge wall opposite the right burners and one 8 inches in diameter in front of the middle burners. The openings in the bridge wall were filled with slag.

No. 15.—*Test of oil fuel in a Hohenstein water-tube marine boiler, October 4, 1902.*

[Eight hours' duration with natural draft, using Oil City Boiler Works burner, under steam.]

Time.	Steam pressure gauge.	Temperature of feed.	Calorimeter.			Height of water in gauge glass.	Temperature.					Pressure on burner (Scotch boiler).
			T₁.	T₂.	Q.		Air in fireroom.	Oil in weighing tank.	Super-heated steam for burners.	Gases at base of stack.	Over platform.	
	Lbs.	° *F.*	° *F.*	° *F.*		*Ins.*	° *F.*	° *F.*	° *F.*	° *F.*	° *F.*	*Lbs.*
9 a. m.....	279	110	404	310	0.986	2.5	94	.....	410	......	170	94
9.15 a. m..	279	116	410	.....	.984	2.75	92	65	410	680	....	93
9.30 a. m..	279	112	409	312	.986	2.5	96	.....	412	......	....	90
9.45 a. m..	279	118	410	.....	.985	.....	97	.....	410	......	....	90
10 a. m ...	279	118	.....	.....	.985	.....	100	.....	410	......	178	90
10.15 a. m.	279	120	.....	.....	.985	3	99	65	418	685	....	90
10.30 a. m.	279	118	.....	.....	.985	2.25	98	.....	420	......	....	90
10.45 a. m.	279	118	.....	.....	.985	2.5	99	.....	420	......	....	92
11 a. m ...	279	120	.....	.....	.985	.....	99	.....	420	......	179	92
11.15 a. m.	279	120	.....	.....	.985	2.75	96	66	410	655	....	92
11.30 a. m.	279	118	.....	310	.984	2.5	96	.....	412	......	....	92
11.45 a. m.	279	118	.....	312	.985	.....	98	.....	412	......	....	92
12 m......	279	120	.....	.....	.985	.....	95	.....	414	......	178	94
12.15 p. m.	279	120	.....	.....	.985	3	88	66	408	625	....	90
12.30 p. m.	279	120	.....	.....	.985	.....	90	.....	404	......	....	90
12.45 p. m.	279	120	.....	.....	.985	2.5	89	.....	410	......	....	92
1 p. m	279	124	.....	.....	.985	.....	89	.....	410	......	172	93
1.15 p. m..	279	122	.....	.....	.985	.....	84	66	410	610	....	92
1.30 p. m..	279	122	.....	.....	.985	3	90	.....	400	......	....	93
1.45 p. m..	276	118	.....	.....	.985	3.25	90	.....	400	......	....	93
2 p. m	275	130	.....	310	.984	3	88	.....	400	......	170	90
2.15 p. m..	275	130	.....	.....	.985	2.25	88	66	400	635	....	90
2.30 p. m..	275	126	.....	.....	.985	2.5	89	.....	400	......	....	90
2.45 p. m..	275	120	.....	.....	.985	.....	88	.....	402	......	....	90
3 p. m	275	122	.....	.....	.985	.....	89	.....	402	......	168	90
3.15 p. m..	275	122	404	.....	.986	.....	89	66	402	585	....	90
3.30 p. m..	275	120	.....	.....	.986	.....	89	.....	398	......	....	96
3.45 p. m..	275	120	.....	312	.987	.....	89	.....	402	......	....	94
4 p. m	279	120	410	.....	.985	2.75	89	.....	404	......	168	90
4.15 p. m..	279	118	408	.....	.986	3	83	66	406	610	....	94
4.30 p. m..	279	120	.....	.....	.986	2.5	83	.....	404	......	....	93
4.45 p. m..	276	118	.....	.....	.986	.....	84	.....	402	......	....	94
5 p. m	276	120	410	310	.984	.....	84	.....	402	.....	178	93
Average ..	278.1	119.9	.....	.....	.985	.....	91.2	65.8	407.4	635.6	173	91.8

State of weather, overcast, with later drizzle.

Barometer at noon, 30.06 at test plant.

Draft opening into furnace, 500 square inches. Deflectors in use after 12 m.

This test was intended to be a reproduction of that of September 22, and was to develope a possible correction to be applied to the records of September 19, 20, and 22, on account of the dirty condition of the boiler during those tests (it having since been blown down and the tubes cleaned of soot).

No. 15.—*Test of oil fuel in a Hohenstein water-tube marine boiler, October 4, 1902.*

[Eight hours' duration with natural draft, using Oil City Boiler Works burner, under steam.]

Time.	Pressure on oil system.	Draft pressure.				Flue gases.			Smoke.	Oil burned per hour.	Steam for burners per hour.	Feed water per hour.
		Furnace.	Combustion chamber.	Tube chamber.	Base of stack.	CO_2.	O.	CO.				
	Lbs.					P. ct.	P. ct.	P. ct.		Lbs.	Lbs.	Lbs.
9 a. m.	45	—0. 14	—0. 15	—0. 25	—0. 50					0	0	0
9.15 a. m.						8. 8	8. 6	0. 6	¼	1, 203	839	13, 363
9.30 a. m.												
9.45 a. m.												
10 a. m.												
10.15 a. m.						8. 8	8. 1	0. 9	¼	1, 095	620	12, 625
10.30 a. m.												
10.45 a. m.												
11 a. m.												
11.15 a. m.						8. 0	9. 9	0. 3	¼	1, 066	630	12, 136
11.30 a. m.												
11.45 a. m.												
12 m.												
12.15 p. m.						8. 4	8. 6	0. 2	¼	1, 019	620	12, 145
12.30 p. m.												
12.45 p. m.												
1 p. m.												
1.15 p. m.						7. 9	9. 6	0. 3	⅛	927	557	11, 058
1.30 p. m.												
1.45 p. m.												
2 p. m.												
2.15 p. m.						7. 2	10. 5	0. 1	⅛	924	466	10, 763
2.30 p. m.												
2.45 p. m.												
3 p. m.												
3.15 p. m.						7. 1	11. 5	0	⅛	940	501	8, 848
3.30 p. m.												
3.45 p. m.												
4 p. m.												
4.15 p. m.						8. 0	10. 0	0. 2	⅛	897	598	10, 838
4.30 p. m.												
4.45 p. m.												
5 p. m.												
Average	45	— . 14	— . 15	— . 25	— . 50	8. 03	9. 60	0. 33	0. 2	1, 009	604	11, 485

The conditions of this trial were similar to those of September 22, with the following exceptions: The deflectors in the furnace front openings were not installed until 12 m. In view of the fact, that they materially increased the rate of evaporation, it is suggested that if this test is to be used in comparison, the record of the first three hours be disregarded. With the same air openings into the furnace as on September 22, and with almost exactly the same percentage of steam used for spraying the oil, it was impossible to burn more than 84 per cent of the oil burned then. This can be accounted for only by the difference in the hygrometric condition on the two days, the air during this run being saturated. This suggests the advisability of adding the hygrometric condition of the atmosphere to the data recorded for each run.

Total pounds feed water, 91,876.

Total pounds steam for burners, 4,831.

Total pounds of oil burned, 8,071.

No. 16.—*Test of oil fuel in a Hohenstein water-tube marine boiler, October 13, 1902.*

[Six hours' duration with 1-inch forced draft, using Oil City Boiler Works burner, under steam.]

Time.	Steam-pressure gauge.	Temperature of feed.	Calorimeter.			Height of water in gauge glass.	Temperature.				Revolutions per minute of fan.	Steam pressure on burner (Scotch boiler).
			TT_1.	T_2.	Q.		Air in fireroom.	Oil in weigh tank.	Superheated steam for burners.	Gases at base of stack.		
	Lbs.	° *F.*	° *F.*	° *F.*		*Ins.*	° *F.*	° *F.*	° *F.*	° *F.*		*Lbs.*
10 a. m....	280	120	408	288	0.972	2.75	107	....	454	......	300	96
10.15 a. m.	278	118	.....	286	.971	.....	110	68	466	670	294	97
10.30 a. m.	280	118	.....	.....	.971	3	110	....	480	......	300	95
10.45 a. m.	280	120	.....	.....	.971	2.50	112	....	480	......	300	95
11 a. m....	275	122	.....	.....	.971	3	112	....	478	......	299	97
11.15 a. m.	285	120	.....	.....	.971	.....	112	68	464	660	302	90
11.30 a. m.	280	120	.....	.....	.971	2.50	112	....	466	......	300	90
11.45 a. m.	265	120	.....	.....	.971	.....	112	....	460	......	298	90
12 m......	280	122	406	.....	.972	2.75	113	....	460	......	303	90
12.15 p. m.	277	120	.....	.....	.971	2.50	114	68	470	695	300	90
12.30 p. m.	280	118	.....	.....	.972	.....	114	....	488	......	304	92
12.45 p. m.	275	122	.....	.....	.971	2.75	114	....	478	......	300	92
1 p. m	280	118	.....	.....	.972	2.50	114	....	510	......	302	87
1.15 p. m..	265	118	.....	.....	.971	.....	116	68	490	720	304	92
1.30 p. m..	280	117	.....	.....	.972	.....	116	....	480	......	305	87
1.45 p. m..	282	118	408	.....	.971	2.25	116	....	486	......	309	91
2 p. m	277	118	.....	.....	.971	2.50	118	....	490	......	305	94
2.15 p. m..	267	118	.....	.....	.971	.....	118	68	488	720	305	89
2.30 p. m..	278	120	.....	.....	.971	.....	118	....	486	......	306	88
2.45 p. m..	275	118	406	.....	.972	.....	118	....	508	......	305	95
3 p. m	271	118	.....	.....	.971	.....	118	....	512	......	304	93
3.15 p. m..	277	120	.....	.....	.972	3	118	68	492	740	306	93
3.30 p. m..	276	120	.....	.....	.971	2.50	118	....	490	......	304	90
3.45 p. m..	277	120	.....	.....	.972	.....	117	....	490	......	305	92
4 p. m	275	120	.....	.....	.971	2.75	117	....	486	......	304	92
Average ..	276.6	119.3	.....	.....	.971	.....	114.6	68	482	701	303	92

State of weather, clear and pleasant.
Barometer at noon, 29.85 inches.
Draft opening into furnace, 670 square inches, except 12 m. to 1 p. m., 800 square inches.

6 a. m., started fires under main boiler; 6.45 a. m., began driving auxiliaries from main boiler; 7 a. m., 275 pounds pressure in main boiler; 9 a. m., started forced draft; 10 a. m., test begins; 11 a. m. to 1 p. m., attempts were made to reduce the smoke, but with the result of reducing the capacity and not increasing the evaporation; 12 m. to 1 p. m., air was admitted above the burners, but this was found to throw the flames toward the bottom of the furnace.

The boiler casing abreast the tube chamber on the right side of the boiler was heated to a cherry red.

No. 16.—*Test of oil fuel in a Hohenstein water-tube marine boiler, October 13, 1902.*

[Six hours' duration with 1-inch forced draft, using Oil City Boiler Works burner, under steam.]

Time.	Draft pressures.				Flue gases.			Hygrometer.		Oil burned per hour.	Steam for spraying per hour.	Feed water per hour.
	Fireroom.	Furnace.	Combustion chamber.	Tube chamber.	CO_2.	O.	CO.	Dry.	Wet.			
					P. ct.	*P. ct.*	*P. ct.*			*Lbs.*	*Lbs.*	*Lbs.*
10 a. m.	1.0	1.0	0.6	0.27						0	0	0
10.15 a. m.			.5	.20	6.0	12.0	0.2	74	65.5			
10.30 a. m.			.5	.20								
10.45 a. m.			.5	.20								
11 a. m.			.5	.22						1,528	376	15,413
11.15 a. m.			.5	.22	6	12.2	.4	77	68			
11.30 a. m.			.5	.22								
11.45 a. m.			.5	.22								
12 m.			.5	.22						1,341	320	13,821
12.15 p. m.			.5	.22	6.6	11.8	.2	77	68.5			
12.30 p. m.			.5	.24								
12.45 p. m.			.5	.27								
1 p. m.			.6	.30						1,451	389	13,980
1.15 p. m.			.55	.28	7	11	0	77	67			
1.30 p. m.			.55	.30								
1.45 p. m.	1.1	1.1	.50	.30								
2 p. m.	1.1	1.1	.55	.30						1,636	304	16,966
2.15 p. m.	1.1	1.1	.55	.28	6.9	10.9	.1	75.5	67.5			
2.30 p. m.	1.0	1.0	.53	.30								
2.45 p. m.	1.0	1.0	.6	.30								
3 p. m.	1.1	1.1	.6	.28						1,759	337	17,853
3.15 p. m.	1.1	1.1	.6	.28	6.9	10.7	.2	77.5	67			
3.30 p. m.	1.1	1.1	.6	.28								
3.45 p. m.	1.1	1.1	.6	.28								
4 p. m.	1.1	1.1	.6	.28						1,664	478	17,261
Average	1.03	1.03	.54	.26	6.57	11.43	.18	76.3	67.3	1,563	367	15,882

In this test it was endeavored to use only enough steam in the burners to spray the oil.

A dish of carbon 12 inches in diameter was deposited in front of the right burners, and one 8 inches in diameter in front of the middle burners. Some carbon was deposited on the lower row of tubes; on the six right tubes for 1 foot from the back wall the deposit was 1 inch thick, but the passages were not choked by it.

Total pounds oil burned, 9,379.

Total pounds steam for spraying, 2,204.

Total pounds feed water, 95,294.

No. 17.—*Test of oil fuel in a Hohenstein water-tube marine boiler October 14, 1902.*

[Four hours' duration with 2-inch forced draft, using Oil City Boiler Works burner, under steam.]

Time.	Steam pressure gauge.	Temperature of feed water.	Calorimeter.			Height of water in gauge glass.	Temperatures.				Revolutions of fan.	Steam pressure on burners (Scotch boilers).
			T₁.	T₂.	Q.		Air in fireroom.	Oil in weigh tank.	Superheated steam for burners.	Gases at base of stack.		
	Lbs.	° *F.*	° *F.*	° *F.*	° *F.*	*Ins.*	° *F.*	° *F.*	° *F.*	° *F.*		*Lbs.*
11 a. m....	270	115	404	302	0.981	2.75	100	.....	568	......	415	93
11.15 a. m.	276	114	404	303	.981	2.5	102	65	564	860	390	91
11.30 a. m.	275	121	404	303	.981	2.5	104	.....	556	......	387	93
11.45 a. m.	265	112	404	302	.981	3	103	.....	568	......	389	90
12 m......	263	120	402	302	.983	2.5	104	.....	578	......	385	87
12.15 p. m.	270	117	402	302	.983	3.5	104	65	564	855	380	90
12.30 p. m.	281	117	404	303	.983	2.5	106	.....	564	......	408	95
12.45 p. m.	276	122	406	303	.981	3	105	.....	560	......	408	92
1 p. m	274	122	406	303	.982	2.75	105	.....	560	......	385	88
1.15 p. m..	275	125	406	303	.981	.....	106	65	560	850	380	88
1.30 p. m..	275	120	406	303	.982	.....	106	.....	558	......	390	89
1.45 p. m..	280	120	404	303	.982	.....	106	.....	560	......	394	91
2 p. m	280	120	406	306	.983	.....	106	.....	554	......	391	93
2.15 p. m..	276	120	406	308	.984	.....	104	65	482	830	392	85
2.30 p. m..	275	120	406	308	.984	.....	104	.....	496	......	393	85
2.45 p. m..	276	120	406	308	.984	.....	104	.....	488	......	392	90
3 p. m	282	120	406	308	.984	.....	102	.....	484	......	393	93
Average ..	274.7	119.1	.....	.....	.982	.....	104	65	545	849	392	90.2

State of weather, partly cloudy.
Barometer at noon, 29.93 inches.
Draft opening into furnace, 830 square inches.

During this test there was considerable soot on the tubes from the preceding test. Also the water was very muddy, it being found necessary to blow down the water column at intervals of 10 minutes toward the end of the test.

Until the last hour of the test, too little steam was used in the burners and the oil was insufficiently sprayed. This, together with the dirty condition of the boiler, accounts for the low rate of evaporation.

No. 17.—*Test of oil fuel in a Hohenstein water-tube marine boiler October 14, 1902.*

[Four hours' duration with 2-inch forced draft, using Oil City Boiler Works burner, under steam.]

Time.	Draft pressures.				Flue gases.			Hygrometer.		Oil burned per hour.	Steam for spraying, per hour.	Feed water, per hour.
	Fireroom.	Furnace.	Combustion chamber.	Tube chamber.	CO$_2$.	O.	CO.	Dry.	Wet.			
					P. ct.	*P. ct.*	*P. ct.*			*Lbs.*	*Lbs.*	*Lbs.*
11 a. m....	2.1	1.7	1.3	0.9						0	0	0
11.15 a. m.	2	1.6	1.2	.9	7.1	11.3	0.4	68.5	59.5			
11.30 a. m.	2.1	1.7	1.3	.9								
11.45 a. m.	2	1.6	1.2	.9								
12 m......	2.1	1.7	1.3	.9						2,612	293	22,097
12.15 p. m.	1.9	1.5	1.2	.85	7	10.8	.4	69	58.5			
12.30 p. m.	2.2	1.8	1.4	.9								
12.45 p. m.	2	1.9	1.4	.9								
1 p. m	2	1.7	1.2	.8						2,429	280	20,305
1.15 p. m..	2	1.6	1.2	.73								
1.30 p. m..	2	1.7	1.3	.74								
1.45 p. m..	2	1.7	1.3	.73								
2 p. m	2	1.7	1.25	.73						2,152	300	19,406
2.15 p. m..	2	1.7	1.3	.75	7.8	10.1	.5	67	67			
2.30 p. m..	2	1.7	1.28	.75								
2.45 p. m..	2	1.7	1.3	.75								
3 p. m	2	1.7	1.3	.75						2,027	572	20,580
Average ..	2.04	1.69	1.28	.82	7.3	10.73	.43	68.2	61.6	2,305	361	20,597

Throughout the test smoke was observed coming from beneath the fireroom. Streams from two hose lines were kept playing into the space, and vents were closed with earth. At the conclusion of the tests the smouldering fire had been quenched. The fire was due to some small timbers being left in the earth under the foundations proper of the boiler.

Total pounds oil burned, 9,220.

Total pounds steam for spraying, 1,445.

Total pounds feed water, 82,388.

Pressure on oil system, 45 pounds.

No. 18.—*Test of oil fuel in a Hohenstein water-tube marine boiler, October 22, 1902.*

[Five hours' duration with 2-inch forced draft, using Oil City Boiler Works burners.]

Time.	Steam-pressure gauge.	Temperature of feed water.	Calorimeter.			Height of water in gauge glass.	Temperature.				Revolutions of fan.	Steam pressure for spraying (Scotch boiler).
			T₁.	T₂.	Q.		Air in fireroom.	Oil in weigh tank.	Superheated steam for burner.	Gases at base of stack.		
	Lbs.	° *F.*	° *F.*	° *F.*	° *F.*	*Ins.*	° *F.*	° *F.*	° *F.*	° *F.*		
11 a. m....	275	120	404	302	0.985	3	94	......	500	......	393	87
11.15 a. m.	270	122	404	302	.984	3	96	59	600	815	379	90
11.30 a. m.	280	125	408	302	.980	3	96	......	576	.....	383	91
11.45 a. m.	280	115	408	302	.980	3	96	......	576	.....	384	93
12 m......	280	115	408	302	.980	3	96	......	596	.....	386	91
12.15 p. m.	275	120	408	302	.980	2.5	96	58	586	860	383	85
12.30 p. m.	272	120	406	302	.981	3	97	......	546	.....	375	89
12.45 p. m.	273	120	402	302	.981	2.75	96	......	540	.....	375	90
1 p. m	276	113	404	304	.983	3	98	......	532	.....	370	90
1.15 p. m..	282	122	408	306	.982	.....	98	58	530	840	377	91
1.30 p. m..	279	121	408	304	.981	.....	98	......	520	.....	380	93
1.45 p. m..	278	122	408	304	.981	.....	97	......	510	.....	380	85
2 p. m	273	122	408	304	.981	.....	98	......	524	.....	382	86
2.15 p. m..	275	120	406	302	.981	.....	100	59	520	845	380	93
2.30 p. m..	276	118	404	302	.982	.....	100	......	500	.....	378	92
2.45 p. m..	278	122	404	302	.982	.....	100	......	518	.....	380	92
3 p. m	280	120	404	302	.982	.....	100	......	510	.....	378	92
3.15 p. m..	275	122	404	304	.983	.....	100	59	506	850	375	90
3.30 p. m..	280	122	404	304	.983	.....	98	......	510	.....	375	90
3.45 p. m..	275	120	404	304	.983	.....	98	......	510	.....	378	91
4 p. m	275	116	404	304	.983	3	98	......	506	.....	380	90
Average ..	276.7	119.9	.....	.....	.982	.....	97.6	58.6	534	842	379.6	90

State of weather, clear.
Barometer at noon, 30.37 inches.
Draft opening into furnace, 800 square inches until noon, then 492 square inches.
7 a. m., lighted burners under main boiler; 7.45 a. m., auxiliaries driven from main boiler; 8 a. m., 275 pounds pressure in main boiler; 10 a. m., started forced draft; 11 a. m., test begins.

No. 18.—*Test of oil fuel in a Hohenstein water-tube marine boiler, October 22, 1902.*

[Five hours' duration with 2-inch forced draft, using Oil City Boiler Works burners.]

Time.	Draft pressures.				Flue gases.			Hygrometer.		Oil per hour.	Steam for spraying per hour.	Feed water per hour.
	Fireroom.	Furnace.	Combustion chamber.	Tube chamber.	CO_2.	O.	CO.	Dry.	Wet.			
					P. ct.	*P. ct.*	*P. ct.*			*Lbs.*	*Lbs.*	*Lbs.*
11 a. m.	2.2	1.8	1.5	0.78	.....	.....	.....	.....	.....	0	0	0
11.15 a. m.	1.95	1.6	1.3	.65	6	7.8	0	57.5	48	2,092	398	20,082
11.30 a. m.	2	1.63	1.38	.7	.....	.....	.....	.....	.....	.....	.....	.....
11.45 a. m.	2	1.65	1.37	.68	.....	.....	.....	.....	.....	.....	.....	.....
12 m.	2.05	1.68	1.38	.68	.....	.....	.....	.....	.....	.....	.....	.....
12.15 p. m.	2.08	1.58	1.25	.65	7	10.6	.2	60.25	49	2,140	601	21,248
12.30 p. m.	2	1.48	1.2	.63	.....	.....	.....	.....	.....	.....	.....	.....
12.45 p. m.	2	1.48	1.23	.62	.....	.....	.....	.....	.....	.....	.....	.....
1 p. m	2.03	1.45	1.26	.65	.....	.....	.....	.....	.....	.....	.....	.....
1.15 p. m.	2	1.45	1.18	.62	7.4	10.7	.1	61.25	50	2,093	626	21,434
1.30 p. m.	2	1.43	1.15	.63	.....	.....	.....	.....	.....	.....	.....	.....
1.45 p. m.	2	1.45	1.18	.63	.....	.....	.....	.....	.....	.....	.....	.....
2 p. m	2	1.43	1.15	.62	.....	.....	.....	.....	.....	.....	.....	.....
2.15 p. m.	2	1.45	1.15	.63	7.4	10.4	.1	64	51	2,098	736	21,094
2.30 p. m.	2	1.45	1.18	.63	.....	.....	.....	.....	.....	.....	.....	.....
2.45 p. m.	2	1.43	1.15	.62	.....	.....	.....	.....	.....	.....	.....	.....
3 p. m	2	1.45	1.15	.63	.....	.....	.....	.....	.....	.....	.....	.....
3.15 p. m.	2	1.45	1.15	.62	7.1	10.3	.2	63.25	51	2,112	765	20,920
3.30 p. m.	2	1.45	1.18	.63	.....	.....	.....	.....	.....	.....	.....	.....
3.45 p. m.	2	1.43	1.15	.63	.....	.....	.....	.....	.....	.....	.....	.....
4 p. m	2	1.43	1.15	.63	.....	.....	.....	.....	.....	.....	.....	.....
Average	2.01	1.51	1.23	.65	6.98	9.96	.12	61.25	49.8	2,107	625	20,956

Pressure on oil system, 45 pounds.
Average draft pressure at base of stack, —.52.
Total pounds of oil burned, 10,535.
Total pounds of steam for spraying, 3,126.
Total pounds feed water, 104,778.

No. 19.—*Test of oil fuel in a Hohenstein water-tube marine boiler, October 25, 1902.*

[Three hours' duration, with 3-inch forced draft, using Oil City Boiler Works burner, under steam.]

Time.	Steam-pressure gauge.	Temperature of feed water.	Calorimeter.			Height of water in gauge glass.	Temperature.					
			T₁.	T₂.	Q.		Outside.		Air in fireroom.	Oil in weigh tank.	Superheated steam for burners.	Gases at base of stack.
							Dry.	Wet.				
	Lbs.	° *F.*	° *F.*	° *F.*	° *F.*	*Ins.*	° *F.*	° *F.*	° *F.*	° *F.*	° *F.*	° *F.*
4 p. m	264	108	400	302	0.983	3	.....	......	111	....	460	......
4.15 p. m..	278	110	402	301	.982	3.5	81	69.5	111	64	476	1,010
4.30 p. m..	276	115	404	301	.981	3	.....	......	110	....	480	......
4.45 p. m..	275	108	401	302	.983	3	.....	......	110	....	488	......
5 p. m	275	105	401	302	.983	3	.....	......	110	....	488	......
5.15 p. m..	280	109	402	302	.983	3.5	73	66	108	65	456	1,090
5.30 p. m..	278	104	402	302	.983	3	.....	......	108	....	456	......
5.45 p. m..	278	114	406	302	.981	3	.....	......	108	....	460	......
6 p. m	275	110	406	302	.981	3.5	.....	......	116	....	464	......
6.15 p. m..	273	110	406	302	.981	3	.....	......	118	65	465	......
6.30 p. m..	270	108	408	308	.983	3	.....	......	118	....	465	......
Average ..	274.7	109.2	.....	.....	.982	.....	77	67.7	112	65	469	1,050

State of weather, clear.
Barometer at noon, 30.14 inches.
Draft opening into furnace, 800 square inches.

7 a. m., started fires under main boiler; 7.45 a. m., auxiliaries driven from main boiler; 8 a. m., 275 pounds pressure in main boiler; 10 a. m., shut down, feed pump disabled; 10.30 a. m., started again; 10.45 a. m., shut down, feed pump again; 11.15 a. m., started again; 11.35 a. m., shut down, once more the feed pump; 2 p. m., started again; 3 p. m., started forced draft; 4 p. m., test begins.

No. 19.—*Test of oil fuel in a Hohenstein water-tube marine boiler, October 25, 1902.*

[Three hours' duration, with 3-inch forced draft, using Oil City Boiler Works burner, under steam.]

Time.	Steam pressure for spraying (Scotch boiler).	Pressure on oil system.	Revolutions per minute of fan.	Draft pressures.					Smoke.	Oil burned per hour.	Steam for spraying per hour.	Water per hour.
				Fireroom.	Furnace.	Combustion chamber.	Tube chamber.	Base of stack.				
	Lbs.	*Lbs.*								*Lbs.*	*Lbs.*	*Lbs.*
4 p. m	92	30	469	3	2.6	2.1	1.1	−0.4	....	0	0	0
4.15 p. m..	92	30	465	3	2.7	2.2	1.2	− .4	2.5	......	......	......
4.30 p. m..	91	30	465	3	2.6	2.2	1.2	− .4	....	......	......	......
4.45 p. m..	88	30	469	3	2.6	2.3	1.2	− .4	....	......	......	......
5 p. m	88	30	463	3.1	2.6	2.25	1.3	− .4	....	2,885	1,015	26,954
5.15 p. m..	88	30	465	3	2.6	2.25	1.3	− .4	4	......	......	......
5.30 p. m..	94	35	463	3	2.6	2.25	1.3	− .4	....	......	......	......
5.45 p. m..	93	35	463	3	2.6	2.25	1.3	− .4	....	......	......	......
6 p. m	92	35	457	3	2.6	2.25	1.3	− .4	....	2,953	1,104	27,162
6.15 p. m..	92	35	458	3.1	2.6	2.25	1.3	− .45	....	......	......	......
6.30 p. m..	90	35	453	3.1	2.6	2.25	1.3	− .50	....	1,607	535	14,117
Average ..	91	32	463	3.02	2.61	2.23	1.25	− .41	3.3	2,978	1,062	27,293

In this test it was endeavored to secure maximum capacity without regard to efficiency. After the second hour the base of the stack was red hot, and the test was stopped at 6.30 to prevent injury to the stack.

There were two disks of carbon 12 inches in diameter opposite the left and middle burners.

Total pounds of oil burned, 7,445.

Total pounds of steam for spraying, 2,654.

Total pounds feed water, 68,233.

Base of stack red hot; impossible to collect samples of flue gases.

No. 20.—*Test of oil fuel in a Hohenstein water-tube marine boiler, October 27, 1902.*

[Seven hours' duration with 1-inch forced draft, using Oil City Boiler Works burners, under steam.]

Time.	Steam-pressure gauge.	Temperature of feed.	Colorimeter.			Height of water in gauge glass.	Temeratures.					Steam pressure for spraying (Scotch boiler).
							Outside.					
			T₁.	T₂.	Q.		Dry.	Wet.	Air in fireroom.	Superheated steam for burners.	Gases at base of stack.	
	Lbs.	° *F.*	° *F.*	° *F.*	° *F.*	*Ins.*	° *F.*	° *F.*	° *F.*	° *F.*	° *F.*	*Lbs.*
12 m......	275	112	406	308	0.984	3	.....	.....	104	410	.....	90
12.15 p. m.	275	118	404	308	.984	3.25	66	64.5	106	416	820	97
12.30 p. m.	276	120	406	308	.984	3	.....	.....	106	414	.....	98
12.45 p. m.	276	120	406	308	.984	3	.....	.....	106	412	.....	90
1 p. m	275	112	406	308	.984	3	.....	.....	106	418	.....	92
1.15 p. m..	276	118	406	308	.984	3	67.5	65.5	106	422	790	92
1.30 p. m..	271	122	404	308	.984	3	.....	.....	110	420	.....	90
1.45 p. m..	275	120	406	306	.983	3	.....	.....	108	420	.....	90
2 p. m	278	125	406	306	.983	3	.....	.....	108	422	.....	90
2.15 p. m..	276	120	406	306	.983	3	69	66	108	414	820	90
2.30 p. m..	273	115	404	306	.983	3	.....	.....	109	424	.....	90
2.45 p. m..	280	119	406	308	.984	3	.....	.....	108	430	.....	90
3 p. m	280	120	406	306	.983	3	.....	.....	108	422	.....	90
3.15 p. m..	275	120	406	306	.983	3	69.25	66.25	112	420	850	92
3.30 p. m..	276	120	406	306	.983	3	.....	.....	110	420	.....	90
3.45 p. m..	280	120	404	306	.984	3	.....	.....	110	426	.....	90
4 p. m	280	117	404	306	.984	3	.....	.....	110	430	.....	90
4.15 p. m..	274	120	404	306	.984	3	69.25	66.25	110	428	815	90
4.30 p. m..	275	118	404	306	.984	3	.....	.....	110	428	.....	92
4.45 p. m..	272	112	404	306	.984	3	.....	.....	110	424	.....	90
5 p. m	284	118	404	306	.984	3	.....	.....	110	426	.....	90
5.15 p. m..	278	118	404	306	.984	2.5	68	65.25	110	420	815	90
5.30 p. m..	274	120	404	306	.984	3	.....	.....	110	416	.....	90
5.45 p. m..	275	120	404	306	.984	3.5	.....	.....	110	412	.....	90
6 p. m	265	122	404	306	.984	3	.....	.....	110	430	.....	88
6.15 p. m..	280	115	404	306	.984	3	.....	.....	108	420	.....	90
6.30 p. m..	275	120	404	306	.984	3	.....	.....	112	410	.....	90
6.45 p. m..	275	120	404	306	.984	3	.....	.....	112	416	.....	92
7 p. m	275	120	404	306	.984	3	.....	.....	112	420	.....	90
Average ..	275.8	118.7	.....	.....	.984	.....	68.1	65.6	108.7	420	818	91

State of weather, overcast; drizzling, noon to 1 p. m.; raining, 6 to 7 p. m.
Barometer at noon, 29.96 inches.
Draft opening into furnace, 800 square inches.

No. 20.—*Test of oil fuel in a Hohenstein water-tube marine boiler, October 27, 1902.*

[Seven hours' duration with 1-inch forced draft, using Oil City Boiler Works burners, under steam.]

Time.	Revolutions per minute of fan.	Draft pressures.					Flue gases.			Oil burned per hour.	Steam for spraying per hour.	Water per hour.
		Fireroom.	Furnace.	Combustion chamber.	Tube chamber.	Base of stack.	CO_2.	O.	CO.			
	Lbs.						*P. ct.*	*P. ct.*	*P. ct.*	*Lbs.*	*Lbs.*	*Lbs.*
12 m	288	1	0.7	0.50	0.20	—0.5	......	......	......	0	0	0
12.15 p. m.	290	1	.8	.53	.27	— .5	8.5	8.9	0.3	......	......	......
12.30 p. m.	289	1	.8	.53	.27	— .5	......	......	......	......	......	......
12.45 p. m.	287	1	.8	.53	.27	— .5	......	......	......	......	......	......
1 p. m	286	.99	.78	.52	.27	— .52	......	......	......	1,935	1,222	19,726
1.15 p. m.	288	1	.8	.53	.27	— .52	9	9	.1	......	......	......
1.30 p. m.	287	1	.8	.53	.27	— .51	......	......	......	......	......	......
1.45 p. m.	288	1	.8	.53	.27	— .51	......	......	......	......	......	......
2 p. m	283	1	.8	.60	.30	— .5	......	......	......	1,938	1,178	20,712
2.15 p. m.	282	1	.8	.60	.30	— .5	8.4	8.8	.1	......	......	......
2.30 p. m.	285	1	.8	.58	.30	— .5	......	......	......	......	......	......
2.45 p. m.	287	1	.8	.60	.30	— .5	......	......	......	......	......	......
3 p. m	285	1	.8	.60	.30	— .5	......	......	......	1,973	1,126	21,615
3.15 p. m.	283	1	.8	.60	.30	— .5	9.4	8.2	0	......	......	......
3.30 p. m.	285	1	.8	.60	.30	— .5	......	......	......	......	......	......
3.45 p. m.	290	1.03	.85	.60	.30	— .5	......	......	......	......	......	......
4 p. m	291	1	.82	.60	.30	— .5	......	......	......	2,008	1,295	21,948
4.15 p. m.	291	1	.8	.60	.30	— .5	8.9	8.5	0	......	......	......
4.30 p. m.	290	1	.82	.60	.30	— .5	......	......	......	......	......	......
4.45 p. m.	289	1	.8	.60	.30	— .5	......	......	......	......	......	......
5 p. m	285	1	.8	.60	.30	— .5	......	......	......	2,010	1,189	22,124
5.15 p. m.	287	1	.8	.60	.30	— .5	8.2	9	.1	......	......	......
5.30 p. m.	292	1.05	.87	.63	.31	— .51	......	......	......	......	......	......
5.45 p. m.	287	1	.8	.60	.30	— .5	......	......	......	......	......	......
6 p. m	285	1.02	.82	.60	.30	— .51	......	......	......	1,967	1,311	21,209
6.15 p. m.	287	1	.8	.53	.31	— .52	......	......	......	......	......	......
6.30 p. m.	286	1	.8	.53	.30	— .51	......	......	......	......	......	......
6.45 p. m.	286	1	.8	.53	.30	— .51	......	......	......	......	......	......
7 p. m	286	1	.8	.53	.31	— .51	......	......	......	1,950	1,325	21,826
Average	287	1	.80	.57	.29	— .50	8.73	8.73	.10	1,969	1,235	21,309

Deposit of carbon, 8 inches diameter opposite right burners.
Temperature of oil in weigh tank, 65° F.
Average pressure on oil system, 81 pounds.
Total pounds of oil burned, 13,781.
Total pounds of steam for spraying, 8,646.
Total pounds of feed water, 149,160.

No. 21.—*Test of oil fuel in a Hohenstein water-tube marine boiler, November 14, 1902.*

[Seven hours' duration with natural draft, using Advance Oil Company's burner, steam.]

Time.	Steam pressure gauge.	Temperature of feed.	Calorimeter.			Height of water in gauge glass.	Temperature.					Scotch boiler pressure gauge.
			T₁.	T₂.	Q.		Outside.		Air in fireroom.	Superheated steam for burners.	Gases at base of stack.	
							Dry.	Wet.				
	Lbs.	° F.	° F.	° F.		Ins.	° F.	° F.	° F.	° F.		Lbs.
9.45 a. m..	275	120	404	304	0.983	3.0	.....	......	70	310	.....	94
10 a. m....	273	120	404	302	.982	2.75	51.5	51.0	69	315	630	95
10.15 a. m.	273	120	406	302	.981	2.75	.....	......	71	310	.....	88
10.30 a. m.	265	120	408	302	.980	2.75	.....	......	75	304	.....	90
10.45 a. m.	275	122	408	302	.980	3.0	.....	......	71	299	.....	89
11 a. m....	274	118	408	302	.980	2.75	53.0	51.75	74	312	620	87
11.15 a. m.	275	120	408	302	.980	2.75	.....	......	77	300	.....	86
11.30 a. m.	270	119	408	302	.980	3.0	.....	......	74	308	.....	90
11.45 a. m.	269	120	402	302	.982	3.0	.....	......	74	304	.....	88
12 m......	280	120	406	302	.981	3.0	56.0	54.0	75	320	640	90
12.15 p. m.	274	119	406	302	.981	3.0	.....	......	74	324	.....	90
12.30 p. m.	270	120	406	304	.982	3.0	.....	......	74	324	.....	90
12.45 p. m.	274	120	406	302	.981	2.75	.....	......	75	326	.....	90
1 p. m	268	119	404	302	.982	3.0	58.0	55.0	76	336	670	90
1.15 p. m..	270	120	406	302	.981	2.75	.....	......	80	320	.....	90
1.30 p. m..	273	122	406	302	.981	2.75	.....	......	76	318	.....	90
1.45 p. m..	272	118	402	302	.982	3.0	.....	......	78	320	.....	90
2 p. m	276	118	406	302	.981	2.75	62.5	57.75	80	326	635	90
2.15 p. m..	276	122	408	302	.980	3.0	.....	......	82	326	.....	90
2.30 p. m..	277	120	404	302	.982	2.75	.....	......	84	326	.....	90
2.45 p. m..	270	120	406	302	.981	2.75	.....	......	82	326	.....	90
3 p. m	275	120	404	302	.982	2.75	63.5	58.25	82	324	645	92
3.15 p. m..	275	120	406	302	.981	3.0	.....	......	83	334	.....	93
3.30 p. m..	275	120	406	302	.981	2.75	.....	......	88	330	.....	92
3.45 p. m..	275	120	406	302	.981	2.75	.....	......	82	230	.....	84
4 p. m	274	120	408	302	.980	2.75	63.0	59.5	81	324	640	90
4.15 p. m..	275	120	406	301	.980	2.75	.....	......	84	342	.....	91
4.30 p. m..	275	120	408	302	.980	2.75	.....	......	90	332	.....	91
4.45 p. m..	275	120	406	302	.981	2.75	.....	......	90	340	.....	91
Average ..	273.4	119.9	.....	.....	.981	.....	58.2	55.3	78.3	321	640	90

Total pounds of oil burned, 7,517.
Total pounds of steam for spraying, 7,237.
Total pounds of water, 84,966.
Average draft pressure in furnace, —0.133 inch.
State of weather, heavy mist until 10.30 a. m., then light mist.
Barometer at noon, 30.23 inches.

Draft opening into furnace, 8.45 to 10.45, 248 square inches; 10.45 to 11.45, 242 square inches; 11.45 to 4.45, 698 square inches; average, 569 square inches; 5.15 a. m., started fires under main boiler; 6 a. m., auxiliaries driven from main boiler; 6.15 a. m., 275 pounds pressure in main boiler; 8.10 to 8.15, shut off burners to overhaul calorimeter; 8.45, began taking data; 9.45, official test starts.

Temperature of oil in weigh tank, 54° F.
Pressure on the oil system, 35 pounds.

The boiler has been thoroughly washed out and the outside of tubes scraped with wire brushes to remove soot.

The burner does not spray the oil sufficiently to produce a jet in which the combustion is selfsupporting. In starting fires it was necessary to keep a piece of burning oil soaked waste in front of each burner for at least a half hour, during which time the oil burned on the floor of the furnace near the back wall. The brick lining would then be sufficiently heated to ignite the oil in the jets by radiation. There was very little combustion in the front half of the furnace.

No. 21.—*Test of oil fuel in a Hohenstein water-tube marine boiler, November 14, 1902.*

[Seven hours' duration with natural draft, using Advance Oil Company's burner, steam.]

Time.	Draft pressures.					Flue gases.			Oil burned per hour.	Steam for spraying per hour.	Water per hour.
	Combustion chamber.	Tube chamber.		Above tubes, below drums.	Base of stack.	CO$_2$.	O.	CO.			
		Front.	Back.								
						P. ct.	*P. ct.*	*P. ct.*	*Lbs.*	*Lbs.*	*Lbs.*
9.45 a. m..	—0.23	—0.21	—0.236	—0.405	—0.56	....	....	....	0	0	0
10 a. m....	— .23	— .21	— .236	— .405	— .56	7.4	9.6	0.8	....	....	....
10.15 a. m.	— .23	— .21	— .24	— .4	— .53	....	....	....	....	....	....
10.30 a. m.	— .23	— .21	— .24	— .396	— .54	....	....	....	....	....	....
10.45 a. m.	— .23	— .21	— .24	— .39	— .54	....	....	....	1,095	1,206	12,009
11 a. m....	— .25	— .225	— .25	— .4	— .52	7.7	9.3	(?)	....	....	....
11.15 a. m.	— .25	— .225	— .25	— .39	— .52	....	....	....	....	....	....
11.30 a. m.	— .25	— .225	— .25	— .39	— .52	....	....	....	....	....	....
11.45 a. m.	— .25	— .225	— .25	— .38	— .52	....	....	....	1,075	1,161	11,892
12 m......	— .22	— .20	— .22	— .38	— .53	8.2	9.4	0.4	....	....	....
12.15 p. m.	— .22	— .20	— .22	— .38	— .54	....	....	....	....	....	....
12.30 p. m.	— .22	— .20	— .22	— .38	— .54	....	....	....	....	....	....
12.45 p. m.	— .22	— .21	— .23	— .38	— .54	....	....	....	1,147	1,148	12,589
1 p. m	— .22	— .206	— .235	— .39	— .54	8.2	9.0	0.4	....	....	....
1.15 p. m..	— .22	— .20	— .22	— .37	— .52	....	....	....	....	....	....
1.30 p. m..	— .22	— .20	— .22	— .37	— .51	....	....	....	....	....	....
1.45 p. m..	— .24	— .21	— .23	— .38	— .52	....	....	....	1,047	987	11,974
2 p. m	— .24	— .21	— .23	— .38	— .52	7.8	9.1	0.3	....	....	....
2.15 p. m..	— .24	— .21	— .24	— .38	— .53	....	....	....	....	....	....
2.30 p. m..	— .24	— .21	— .24	— .38	— .53	....	....	....	....	....	....
2.45 p. m..	— .24	— .21	— .24	— .38	— .52	....	....	....	1,108	906	12,799
3 p. m.....	— .24	— .21	— .24	— .38	— .52	8.0	9.2	0.1	....	....	....
3.15 p. m..	— .23	— .21	— .23	— .38	— .52	....	....	....	....	....	....
3.30 p. m..	— .23	— .21	— .23	— .38	— .52	....	....	....	....	....	....
3.45 p. m..	— .23	— .21	— .23	— .38	— .52	....	....	....	1,039	925	12,180
4 p. m.....	— .23	— .21	— .22	— .37	— .50	7.7	9.3	0.1	....	....	....
4.15 p. m..	— .23	— .21	— .22	— .37	— .50	....	....	....	....	....	....
4.30 p. m..	— .25	— .21	— .22	— .37	— .50	....	....	....	....	....	....
4.45 p. m..	— .25	— .21	— .22	— .37	— .50	....	....	....	1,006	904	11,523
Average...	— .234	— .210	— .233	— .383	— .525	7.86	9.27	.035	1,074	1,034	12,138

The burners required continual adjustment, due probably to the fact that the oil in the burner is admitted into a steam chamber against a pressure. A slight increase in the pressure of the steam (oil pressure being constant) has the effect of throttling the oil, while if the steam pressure be reduced, even slightly, the oil is ejected in gulps. With 35 pounds pressure on the oil and 90 pounds of steam and both oil and steam valves wide open, no oil is ejected from the burner. It is then necessary to throttle the steam considerably, probably until the steam pressure at the burner is reduced to very nearly that of the oil, thus a satisfactory adjustment is difficult.

During this test, as well as on preliminary trials, it was found that if the amount of steam used for spraying was reduced below 8 per cent of the water evaporated the spray became so coarse that oil was thrown on to the floor of the furnace.

There was no apparent effect due to the rifling of the burner orifice. It is probable that to produce the desired result the rifling should be developed into vanes set in the burner orifice.

The jet produced was of small diameter and great velocity.

There was no deposit of carbon in the furnace.

No. 22.—*Test of oil fuel in a Hohenstein water-tube marine boiler, November 17, 1902.*

[Eight hours' duration with natural draft, using Advance Oil Company's burner, under air.]

Time.	Steam-pressure gauge.	Temperature of feed.	Calorimeter.			Height of water in gauge glass.	Temperature.					
							Outside.					
			T₁.	T₂.	Q.		Dry.	Wet.	Air in fireroom.	Oil in weigh tank.	Air for burner.	Gases at base of stack.
	Lbs.	° *F.*	° *F.*	° *F.*		*Ins.*	° *F.*	° *F.*	° *F.*	° *F.*	° *F.*	° *F.*
9.30 a. m..	275	118	404	308	0.985	3	......	.....	74	.....	238	.....
9.45 a. m..	275	118	406	309	.985	3.25	......	.....	78	.....	256	.....
10 a. m ...	275	116	407	308	.984	3	53.5	50	76	56	260	650
10.15 a. m.	275	120	406	308	.984	3	......	.....	78	.....	258	.....
10.30 a. m.	275	118	408	308	.983	3.75	......	.....	78	.....	250	.....
10.45 a. m.	275	118	408	308	.984	3	......	.....	80	.....	250	.....
11 a. m ...	275	120	408	308	.983	3	54.75	51	78	56	254	650
11.15 a. m.	276	120	408	308	.984	3	......	.....	88	.....	255	.....
11.30 a. m.	275	120	406	308	.984	3	......	.....	80	.....	254	.....
11.45 a. m.	275	120	406	308	.984	3	......	.....	80	.....	252	.....
12 m......	274	120	406	308	.984	3	56	52	80	56	250	648
12.15 p. m.	273	120	406	308	.984	3	......	.....	80	.....	248	.....
12.30 p. m.	273	120	404	308	.985	3	......	.....	82	.....	248	.....
12.45 p. m.	274	120	406	308	.984	2.75	......	.....	83	.....	244	.....
1 p. m	275	120	406	308	.984	3	58.75	53.75	84	56	244	630
1.15 p. m .	275	120	404	308	.985	3	......	.....	84	.....	238	.....
1.30 p. m .	270	122	402	308	.986	3	......	.....	84	.....	238	.....
1.45 p. m .	270	120	402	308	.986	2.5	......	.....	84	.....	238	.....
2 p. m	274	118	402	308	.986	2.5	58.5	54	84	56	236	635
2.15 p. m .	270	120	406	308	.984	3	......	.....	84	.....	236	.....
2.30 p. m .	271	120	402	308	.986	2.5	......	.....	81	.....	238	.....
2.45 p. m .	279	118	402	308	.986	3	......	.....	81	.....	236	.....
3 p. m	273	120	406	308	.984	3	58.75	54	81	56	236	630
3.15 p. m .	275	120	404	308	.985	3	......	.....	84	.....	234	.....
3.30 p. m .	270	120	408	308	.983	3	......	.....	84	.....	236	.....
3.45 p. m .	275	120	406	308	.984	3	......	.....	84	.....	234	.....
4 p. m	275	120	406	308	.984	3	59	54.5	84	56	235	640
4.15 p. m .	275	120	408	308	.983	3	......	.....	82	.....	232	.....
4.30 p. m .	270	123	404	308	.985	3	......	.....	82	.....	236	.....
4.45 p. m .	272	118	404	308	.985	3	......	.....	81	.....	240	.....
5 p. m	270	118	406	308	.984	3	58.5	54.5	82	56	236	655
5.15 p. m .	275	120	406	308	.984	3	......	.....	80	.....	236	.....
5.30 p. m .	275	120	406	308	.984	3.5	......	.....	85	.....	238	.....
Average ..	273.8	119.5	.....	.....	.984	.....	57.2	53	81.5	56	243	642

It may be of interest to note the amount of steam required to work the Rand air compressors. From a series of special tests made with these compressors it was found that it required about 35.7 I. H. P. to work the compressors at the speed made during these experiments. The evaporative water consumption, therefore, appears as follows: 35.7 I. H. P. × 34.5 = 1,231.5 pounds of steam consumed per hour by compressors.

State of weather, misty and cloudy.

Barometer at noon, 30.16 inches.

Draft openings into furnace: 8.30 to 4.30, 358 square inches; 4.30 to 5.30, 448 square inches; average, 369 square inches.

4.45 a. m., started fires in main boiler; 6 a. m., auxiliaries driven from main boiler; 6.15 a. m., 275 pounds pressure in main boiler; 9.30 a. m., test begins.

The notes on the run of the 14th instant apply for the most part to this test as well.

No. 22.—*Test of oil fuel in a Hohenstein water-tube marine boiler, November 17, 1902.*

[Eight hours' duration with natural draft, using Advance Oil Company's burner, under air.]

Time.	Draft pressures.						Smoke.	Revolutions per minute, air compressors.	Oil burned per hour.	Water per hour.
	Furnace.	Combustion chamber.	Tube chamber.		Above tubes, below drum.	Base of stack.				
			Front.	Back.						
									Lbs.	*Lbs.*
9.30 a. m	......	......	......	......	......	......	.....	94	0	0
9.45 a. m	......	......	......	......	......	......	.....	96	......	......
10 a. m	......	......	......	......	......	......	0.125	84	......	......
10.15 a. m	......	......	......	......	......	......	.....	86	......	......
10.30 a. m	......	......	......	......	......	......	.....	87	1,089	12,472
10.45 a. m	......	......	......	......	......	......	.....	92	......	......
11 a. m	......	......	......	......	......	......	0	90	......	......
11.15 a. m	−0.13	−0.23	−0.22	−0.24	−0.40	−0.51	.....	90	......	......
11.30 a. m	− .13	− .23	− .21	− .24	− .40	− .52	.....	90	1,115	12,435
11.45 a. m	− .13	− .23	− .21	− .24	− .40	− .52	.....	90	......	......
12 m	− .13	− .23	− .21	− .24	− .40	− .54	.125	90	......	......
12.15 p. m	− .13	− .23	− .21	− .24	− .40	− .52	.....	90	......	......
12.30 p. m	− .13	− .23	− .21	− .24	− .40	− .52	.....	90	1,129	13,102
12.45 p. m	− .13	− .23	− .21	− .24	− .40	− .52	.....	90	......	......
1 p. m	− .13	− .23	− .21	− .24	− .39	− .52	0	90	......	......
1.15 p. m	− .13	− .23	− .21	− .24	− .39	− .51	.....	90	......	......
1.30 p. m	− .13	− .23	− .21	− .23	− .39	− .51	.....	90	1,057	12,466
1.45 p. m	− .13	− .23	− .21	− .23	− .39	− .51	.....	90	......	......
2 p. m	− .13	− .23	− .21	− .23	− .39	− .51	.125	90	......	......
2.15 p. m	− .13	− .23	− .21	− .23	− .39	− .51	.....	90	......	......
2.30 p. m	− .13	− .23	− .21	− .23	− .38	− .51	.....	90	1,063	12,614
2.45 p. m	− .125	− .22	− .20	− .21	− .37	− .50	.....	90	......	......
3 p. m	− .12	− .22	− .20	− .23	− .39	− .50	0	90	......	......
3.15 p. m	− .13	− .22	− .20	− .23	− .38	− .51	.....	90	......	......
3.30 p. m	− .13	− .22	− .20	− .23	− .38	− .51	.....	90	1,028	12,207
3.45 p. m	− .13	− .22	− .20	− .23	− .38	− .51	.....	90	......	......
4 p. m	− .13	− .22	− .20	− .23	− .38	− .51	.125	90	......	......
4.15 p. m	− .13	− .22	− .20	− .23	− .38	− .51	.....	90	......	......
4.30 p. m	− .12	− .22	− .20	− .23	− .38	− .51	.....	90	1,074	12,417
4.45 p. m	− .12	− .22	− .20	− .23	− .38	− .52	.....	90	......	......
5 p. m	− .12	− .22	− .20	− .22	− .38	− .52	.125	90	......	......
5.15 p. m	− .12	− .22	− .20	− .22	− .38	− .52	.....	90	......	......
5.30 p. m	− .12	− .22	− .20	− .22	− .38	− .52	.....	90	1,121	12,780
Average	− .128	− .225	− .205	− .232	− .388	− .514	.125	90	1,084.5	12,562

There was no opportunity to determine whether the combustion in the jet is self-supporting when air is used as the spraying agent, inasmuch as steam must be used in the burners until there is sufficient steam pressure in the main boiler to drive the air compressor.

At the end of the test there was no deposit of carbon in the furnace.

The rear wall of the furnace was white hot and cracked in several places as a result of this run, indicating a local heat greater than that ordinarily developed in this furnace.

Per cent of flue gases: Apparatus broken.
Total pounds oil burned, 8,676.
Total pounds water, 100,493.
Air pressure for spraying, 35 pounds.
Pressure on oil system, 25 pounds.

No. 23.—*Test of oil fuel in a Hohenstein water-tube marine boiler, November 28, 1902.*

[Eight hours' duration with natural draft, using Branch crude-oil burner, steam.]

Time.	Steam pressure gauge.	Temperature of feed.	Calorimeter			Height of water in gauge-glass.	Temperature.				Steam pressure for spraying (Scotch boiler).	Pressure on oil system.
			T₁.	T₂.	Q.		Air in fireroom.	Oil in weigh tank.	Steam for burner.	Gases at base of stack.		
	Lbs.	° *F.*	° *F.*	° *F.*		*Ins.*	° *F.*					
8.15 a. m.	275	118	404	310	0.986	2	65	.....	374	.....	85	55
8.30 a. m.	272	118	404	308	.985	2.5	68	46	372	710	89	55
8.45 a. m.	275	118	408	310	.985	2.25	70	.....	374	.....	90	55
9 a. m.	274	117	408	310	.985	2.5	70	.....	374	.....	94	55
9.15 a. m.	274	120	406	308	.984	2	65	.....	368	.....	92	55
9.30 a. m.	275	120	408	310	.985	2	65	46	370	710	90	55
9.45 a. m.	275	120	408	310	.985	2.75	70	.....	372	.....	90	55
10 a. m.	275	118	408	310	.985	2	73	.....	372	.....	90	55
10.15 a. m.	277	120	408	310	.985	2	72	.....	372	.....	90	55
10.30 a. m.	276	120	408	310	.985	2	74	46	372	718	91	55
10.45 a. m.	275	120	408	308	.983	2.25	74	.....	372	.....	92	55
11 a. m.	270	120	408	310	.985	2	72	.....	378	.....	94	55
11.15 a. m.	275	121	408	310	.985	2	73	.....	378	.....	90	55
11.30 a. m.	274	118	402	310	.987	2	75	46	378	720	90	55
11.45 a. m.	270	120	404	310	.986	2	75	.....	374	.....	90	55
12 m.	270	121	402	310	.987	2.25	74	.....	374	.....	93	55
12.15 p. m.	270	120	402	310	.987	1.5	73	.....	376	.....	92	55
12.30 p. m.	276	124	406	310	.985	2.75	73	46	374	680	92	55
12.45 p. m.	274	120	404	308	.985	2.5	75	.....	376	.....	93	55
1 p. m.	275	122	406	310	.986	2	73	.....	360	.....	94	55
1.15 p. m.	273	120	404	310	.986	1.5	75	.....	364	.....	95	55
1.30 p. m.	275	120	408	310	.985	2.5	75	46	366	(?)	95	55
1.45 p. m.	277	120	406	308	.984	2.5	72	.....	370	.....	95	55
2 p. m.	280	120	408	308	.983	2.5	72	.....	366	.....	92	55
2.15 p. m.	275	120	406	308	.984	2.5	70	.....	366	.....	91	55
2.30 p. m.	275	120	404	308	.985	2.5	71	46	368	680	92	55
2.45 p. m.	276	119	404	308	.985	2.5	76	.....	368	.....	90	55
3 p. m.	274	120	406	308	.984	2.5	69	.....	366	.....	90	55
3.15 p. m.	275	120	406	308	.984	2.5	70	.....	362	.....	90	55
3.30 p. m.	278	120	404	308	.985	1	74	46	364	675	90	55
3.45 p. m.	275	118	408	308	.983	2	74	.....	364	.....	95	55
4 p. m.	275	120	406	308	.984	1.5	76	.....	366	.....	94	55
4.15 p. m.	275	120	406	308	.984	2	77	.....	368	.....	90	55
Average	274.5	119.8	.....	.....	.985	.....	72	46	370	699	91.5	55

State of weather, cloudy.
Barometer at noon, 30.14 inches.
Draft opening into furnace, 476 square inches.
Total pounds of oil burned, 10,117.
Total pounds steam for burners, 9,885.
Total pounds feed water, 116,120.

No. 23.—*Test of oil fuel in a Hohenstein water-tube marine boiler, November 28, 1902.*

[Eight hours' duration with natural draft, using Branch crude-oil burner, steam.]

Time.	Draft pressures.						Smoke.	Oil burned per hour.	Steam for burners per hour.	Feed water per hour.
	Furnace.	Combustion chamber.	Tube chamber.		Above tubes, below drums.	Base of stack.				
			Front.	Back.						
								Lbs.	*Lbs.*	*Lbs.*
8.15 a. m ..	—0. 12	—0. 22	—0. 19	—0. 22	—0. 41	0. 58	....	0	0	0
8.30 a. m ..	— . 13	— . 22	— . 20	— . 24	— . 43	. 61	1. 5	......	......	......
8.45 a. m ..	— . 13	— . 24	— . 20	— . 24	— . 42	. 57	....	......	......	......
9 a. m	— . 15	— . 23	— . 20	— . 24	— . 42	. 56	....	......	......	......
9.15 a. m ..	— . 15	— . 24	— . 21	— . 24	— . 40	. 59	....	1, 310	1, 320	14, 771
9.30 a. m ..	— . 13	— . 22	— . 19	— . 22	— . 42	. 57	1	......	......	......
9.45 a. m ..	— . 13	— . 22	— . 19	— . 22	— . 42	. 57	....	......	......	......
10 a. m	— . 13	— . 22	— . 19	— . 21	— . 40	. 56	....	......	......	......
10.15 a. m .	— . 13	— . 22	— . 20	— . 22	— . 40	. 57	....	1, 382	1, 494	15, 195
10.30 a. m .	— . 13	— . 22	— . 19	— . 21	— . 40	. 58	1	......	......	......
10.45 a. m .	— . 13	— . 22	— . 19	— . 21	— . 41	. 54	....	......	......	......
11 a. m	— . 14	— . 24	— . 19	— . 22	— . 41	. 55	....	......	......	......
11.15 a. m .	— . 14	— . 24	— . 20	— . 22	— . 42	. 60	....	1, 315	1, 383	14, 863
11.30 a. m .	— . 14	— . 24	— . 20	— . 21	— . 39	. 54	. 25	......	......	......
11.45 a. m .	— . 15	— . 22	— . 20	— . 23	— . 42	. 58	....	......	......	......
12 m	— . 15	— . 22	— . 20	— . 23	— . 42	. 58	....	......	......	......
12.15 p. m .	— . 14	— . 22	— . 20	— . 22	— . 42	. 55	....	1, 272	1, 283	14, 937
12.30 p. m .	— . 13	— . 24	— . 20	— . 22	— . 41	. 56	. 25	......	......	......
12.45 p. m .	— . 15	— . 23	— . 20	— . 21	— . 41	. 55	....	......	......	......
1 p. m	— . 14	— . 22	— . 19	— . 21	— . 40	. 53	....	......	......	......
1.15 p. m ..	— . 15	— . 22	— . 19	— . 21	— . 39	. 53	....	1, 209	1, 129	14, 098
1.30 p. m ..	— . 15	— . 22	— . 19	— . 21	— . 39	. 53	(?)	......	......	......
1.45 p. m ..	— . 13	— . 22	— . 19	— . 22	— . 39	. 54	....	......	......	......
2 p. m	— . 13	— . 22	— . 19	— . 22	— . 39	. 53	....	......	......	......
2.15 p. m ..	— . 13	— . 22	— . 19	— . 22	— . 39	. 53	....	1, 217	1, 070	14, 091
2.30 p. m ..	— . 13	— . 23	— . 20	— . 21	— . 39	. 56	0	......	......	......
2.45 p. m ..	— . 13	— . 23	— . 20	— . 21	— . 39	. 56	....	......	......	......
3 p. m	— . 13	— . 22	— . 20	— . 21	— . 38	. 54	....	......	......	......
3.15 p. m ..	— . 14	— . 22	— . 19	— . 21	— . 41	. 53	....	1, 198	1, 063	14, 123
3.30 p. m ..	— . 13	— . 22	— . 19	— . 21	— . 40	. 54	. 25	......	......	......
3.45 p. m ..	— . 13	— . 22	— . 20	— . 22	— . 38	. 53	....	......	......	......
4 p. m	— . 13	— . 23	— . 20	— . 22	— . 40	. 54	....	......	......	......
4.15 p. m ..	— . 13	— . 23	— . 20	— . 22	— . 40	. 54	....	1, 214	1, 143	14, 042
Average ...	— . 136	— . 125	— . 196	— . 219	— . 404	— . 556	. 61	1, 265	1, 236	14, 515

5 a. m., started fires under main boiler; 6 a. m., auxiliaries driven from main boiler; 6.15 a. m., 275 pounds pressure in main boiler; 8.15 a. m., test begins.

Before this test the boiler had been washed out and the tubes cleaned of soot. The furnace was filled with earth to a level of 5 inches below the burners. Air uptakes of brick 4 inches deep were built in the way of each of the front openings of the furnace. This was done by direction of a representative of the burner in order (as he expressed it) to cut down the heated surface.

The filling up of a portion of the furnace with earth reduced the volume of the furnace to such an extent as to interfere with the capacity output of evaporation of the oil fusel installation under test.

From time to time during the test it was suggested to the representative who operated the burners that a higher efficiency might be obtained with a reduced consumption of oil, and that the amount of steam used in atomizing might be reduced. The burner sprays well and is easily adjusted. A comparatively high oil pressure is required. The burner must be taken down and disassembled to be cleaned.

No. 24.—*Test of oil fuel in a Hohenstein water-tube marine boiler, December 1, 1902.*

[Four hours' duration with 2-inch forced draft, using Branch crude-oil burner, steam.]

Time.	Steam-pressure gauge.	Temperature of feed.	Calorimeter.			Height of water in gauge glass.	Temperature.				Steam pressure for spraying, Scotch boiler.	Pressure on oil system.
			T_1.	T_2.	Q.		Air in fireroom.	Oil in weighing tank.	Steam for burner.	Gases at base of stack.		
	Lbs.	° *F.*	° *F.*	° *F.*		*Ins.*	° *F.*	° *F.*	° *F.*	° *F.*	*Lbs.*	*Lbs.*
10.15 a. m.	278	110	404	300	0.981	2.5	77	.....	380	.....	85	55
10.30 a. m.	275	108	402	298	.980	2.5	78	42	382	805	95	55
10.45 a. m.	275	120	400	298	.981	2.5	79	.....	376	.....	94	55
11 a. m....	275	112	402	300	.981	2.5	80	.....	366	.....	94	55
11.15 a. m.	276	118	400	298	.981	2.5	81	.....	370	.....	94	55
11.30 a. m.	275	108	402	300	.981	2.5	82	42	370	770	95	55
11.45 a. m.	276	110	402	300	.981	2.5	82	.....	372	.....	94	55
12 m	277	110	400	300	.982	2.5	83	.....	380	.....	92	55
12.15 p. m.	277	110	402	300	.981	2.5	83	.....	382	.....	95	55
12.30 p. m.	276	108	402	298	.980	2.5	83	42	390	805	95	55
12.45 p. m.	275	106	400	298	.981	2.5	83	.....	388	.....	95	55
1 p. m	278	108	400	300	.982	2.5	83	.....	382	.....	95	55
1.15 p. m..	276	112	402	300	.981	2.5	83	.....	380	.....	95	55
1.30 p. m..	275	114	400	300	.982	2.5	83	42	376	805	96	55
1.45 p. m..	279	112	402	300	.981	2.5	84	.....	378	.....	96	55
2 p. m	280	98	400	300	.982	2.5	85	.....	382	.....	96	55
2.15 p. m..	278	110	402	300	.981	2.5	85	.....	380	.....	95	55
Average ..	276.5	110.2	.....	.....	.981	.....	82	42	378	796	94.2	55

State of weather, partly cloudy to clear.
Barometer at noon, 30.10 inches.
Draft openings into furnace, 476 square inches.

7 a. m., started fires under main boiler; 8 a. m., auxiliaries driven from main boiler; 8.15 a. m., 275 pounds pressure in main boiler; 10 a. m., started forced draft; 11.15 a. m., test begins.

No. 24.—*Test of oil fuel in a Hohenstein water-tube marine boiler, December 1, 1902.*

[Four hours' duration with 2-inch forced draft, using Branch crude-oil burner, steam.]

Time.	Draft pressures.							Smoke.	Revolutions of fan.	Oil burned per hour.	Steam for burner per hour.	Feed water per hour.
				Tube chamber.								
	Fireroom.	Furnace.	Combustion chamber.	Front.	Back.	Above tubes, below drums.	Base of stack.					
										Lbs.	*Lbs.*	*Lbs.*
10.15 a. m.	2	1.6	1.0	1.1	0.9	—0.25	—0.55	......	383	0	0	0
10.30 a. m.	2	1.6	1.0	1.1	.9	— .25	— .56	0.5	383	......	......	......
10.45 a. m.	2	1.6	1.0	1	.9	— .18	— .54	......	384	......	......	......
11 a. m....	2	1.6	1.0	1	.9	— .23	— .55	......	381	......	......	......
11.15 a. m.	2	1.6	1.0	1	.9	— .23	— .55	......	383	1,975	1,110	19,520
11.30 a. m.	2	1.6	1.0	1	.9	— .18	— .56	.25	382	......	......	......
11.45 a. m.	2	1.6	1.0	1	.9	— .22	— .50	......	381	......	......	......
12 m	2	1.6	1.0	1	.9	— .22	— .54	......	382	......	......	......
12.15 p. m.	2	1.6	1.0	1	.9	— .22	— .50	......	381	1,994	1,065	19,805
12.30 p. m.	2	1.6	1.0	1	.9	— .22	— .55	0	383	......	......	......
12.45 p. m.	2	1.6	1.0	1	.9	— .22	— .50	......	382	......	......	......
1 p. m	2	1.6	1.0	1	.9	— .22	— .50	......	383	......	......	......
1.15 p. m..	2	1.6	1.0	1	.9	— .22	— .55	......	383	2,008	1,019	20,298
1.30 p. m..	2	1.6	1.0	1	.9	— .22	— .50	0	383	......	......	......
1.45 p. m..	2	1.6	1.0	1	.9	— .22	— .53	......	382	......	......	......
2 p. m	2	1.6	1.0	1	.9	— .22	— .54	......	381	......	......	......
2.15 p. m..	2	1.6	1.0	1	.9	— .22	— .53	......	381	2,018	1,147	20,505
Average ..	2	1.6	1.0	1.01	.9	— .22	— .532	.375	382	1,999	1,085	20,032

Before this test the boiler was blown "half a glass."
The arrangement of the furnace was the same as on November 28.
Total pounds oil burned, 7,995.
Total pounds steam for burner, 4,341.
Total pounds feed water, 80,128.

No. 25.—*Test of oil fuel in a Hohenstein water-tube marine boiler, December 2, 1902.*

[Three hours' duration with 2-inch forced draft, using Branch crude oil burner, air.]

Time.	Steam pressure gauge.	Feed temperature.	Calorimeter.			Height of water in gauge glass.	Temperature.				Revolutions of air compressor.	Air pressure for spraying.
			T₁.	T₂.	Q.		Air in fireroom.	Oil in weighing tank.	Air for burner.	Gases at base of stack.		
	Lbs.	° *F.*	° *F.*	° *F.*		*Ins.*	° *F.*	° *F.*	° *F.*	° *F.*		*Lbs.*
11 a. m....	275	120	404	298	0.979	2.25	78	.....	340	.....	91	50
11.15 a. m.	275	112	402	298	.980	2.25	80	.....	340	.....	87	50
11.30 a. m.	278	110	400	298	.981	2.25	80	46	320	805	93	50
11.45 a. m.	274	108	400	298	.981	2.25	81	.....	338	.....	80	50
12 m......	275	108	402	298	.980	1.75	82	....	338	.....	79	50
12.15 p. m.	278	110	402	300	.981	2.25	83	.....	336	.....	77	49
12.30 p. m.	274	112	400	300	.982	2.00	84	46	324	775	74	43
12.45 p. m.	278	108	402	300	.981	2.25	84	.....	318	.....	78	49
1 p. m	274	109	400	300	.982	2.25	85	.....	308	.....	75	49
1.15 p. m..	277	112	402	300	.981	2.5	85	.....	320	.....	77	50
1.30 p. m..	275	110	400	300	.982	2.5	85	46	316	755	75	49
1.45 p. m..	280	108	400	300	.982	2.5	85	.....	312	.....	74	50
Average ..	266.1	110.6	.....	.....	.981	.....	82.7	46	326	778	80	49.1

State of weather, clear and dry.
Barometer at noon, 29.96 inches.
Draft opening into furnace, 476 square inches.
7 a. m., started fires under main boiler; 7.45 a. m., auxiliaries driven from main boiler; 8 a. m., 275 pounds pressure in main boiler; 10 a. m., started forced draft; 11 a. m., test begins.

No. 25.—*Test of oil fuel in a Hohenstein water-tube marine boiler, December 2, 1902.*

[Three hours' duration with 2-inch forced draft, using Branch crude oil burner, air.]

Time.	Pressure on oil system.	Draft pressures.							Smoke.	Revolutions of fan.	Oil burned per hour.	Feed water per hour.
		Fireroom.	Furnace.	Combustion chamber.	Tube chamber.		Above tubes, below drums.	Base of stack.				
					Front.	Back.						
	Lbs.										*Lbs.*	*Lbs.*
11 a. m....	30	2	1.6	1.0	1.0	1.0	--0.3	—0.42	....	395	0	0
11.15 a. m.	30	2	1.6	1.0	1.0	1.0	- - .3	— .42	....	396	......	....
11.30 a. m.	30	2	1.6	1.0	1.0	1.0	— .3	— .42	1.0	396	......	....
11.45 a. m.	30	2	1.6	1.0	1.0	1.0	— .3	— .42	....	394	......	....
12 m......	30	2	1.6	1.0	1.0	1.0	— .3	— .42	....	393	2,005	19,910
12.15 p. m.	30	2	1.6	1.0	1.0	1.0	— .3	— .42	....	391	......	....
12.30 p. m.	30	2	1.6	1.0	1.0	1.0	— .3	— .42	1.0	390	......	....
12.45 p. m.	30	2	1.6	1.0	1.0	1.0	— .3	— .42	....	389	......	....
1 p. m	30	2	1.6	1.0	1.0	1.0	— .3	— .42	....	390	1,922	19,976
1.15 p. m..	30	2	1.6	1.0	1.0	1.0	— .3	— .43	....	389	......	....
1.30 p. m..	30	2	1.6	1.0	1.0	1.0	— .3	— .43	.25	391	......	....
1.45 p. m..	30	2	1.6	1.0	1.0	1.0	— .3	— .42	....	395	1,456	14,532
Average ..	30	2	1.6	1.0	1.0	1.0	— .3	— .422	.75	392	1,794	18,139.39

Before this test the boiler was blown down "half a glass."
The arrangement of the furnace was the same as on November 28.
After running 2¾ hours the test was stopped on account of lack of oil.
Total pounds oil burned, 5,883.
Total pounds feed water, 54,418.

No. 26.—*Test of oil fuel in a Hohenstein water-tube marine boiler, December 4, 1902.*

[Four hours' duration with 2-inch forced draft, using Branch crude-oil burner, air.]

Time.	Steam pressure gauge.	Temperature of feed.	Calorimeter.			Height of water in gauge glass.	Temperature.				Revolutions of air compressor.	Air pressure for burners.
			T_1.	T_2.	Q.		Air in fireroom.	Oil in weigh tank.	Air for burner.	Gases at base of stack.		
	Lbs.	° *F.*	° *F.*	° *F.*			° *F.*	° *F.*	° *F.*	° *F.*		*Lbs.*
11 a. m....	277	110	410	301	0.979	2.25	81	.....	332	.....	53	49
11.15 a. m.	278	113	410	300	.978	2.5	80	.....	336	.....	52	49
11.30 a. m.	275	100	408	300	.979	2.5	80	46	340	720	53	49
11.45 a. m.	275	110	408	300	.979	2.5	80	.....	330	.....	52	50
12 m......	275	114	408	300	.979	2.5	80	.....	330	.....	53	49
12.15 p. m.	278	110	408	300	.979	2.5	80	.....	332	.....	53	49
12.30 p. m.	274	90	408	300	.979	2.25	80	46	336	760	54	50
12.45 p. m.	278	108	410	300	.978	2.5	79	.....	342	.....	53	49
1 p. m	276	104	408	300	.979	2.5	79	.....	342	.....	53	49
1.15 p. m..	276	108	408	300	.979	2.5	80	.....	334	.....	53	49
1.30 p. m..	276	113	408	300	.979	2.5	80	46	330	740	53	49
1.45 p. m..	280	112	408	300	.979	2.5	80	.....	334	.....	55	50
2 p. m	277	113	408	300	.979	2.5	78	.....	334	.....	54	49
2.15 p. m..	275	108	406	300	.980	2.5	81	.....	338	.....	53	49
2.30 p. m..	276	112	408	300	.979	2.5	81	46	332	.....	53	49
2.45 p. m..	275	112	410	300	.978	2.5	81	.....	318	.....	53	49
3 p. m	275	120	408	300	.979	1.75	80	.....	316	.....	53	49
Average ..	276.2	109.2	.....	.....	.979	.....	80	46	333	740	53.1	49.2

State of weather, heavy mist.
Barometer at noon, 30.04 inches.
Draft opening into furnace, 680 square inches.

7 a. m., started fires under main boiler; 8 a. m., auxiliaries driven from main boiler; 8.10 a. m., 275 pounds pressure on main boiler; 10 a. m., started forced draft; 11 a. m., test begins.

Before this test the boiler had been blown down "half a glass" and the earth in the furnace removed. (This had melted and caked to a depth of 3 inches and the earth on the bottom was still red hot eighteen hours after the burners were extinguished.)

No. 26.—*Test of oil fuel in a Hohenstein water-tube marine boiler, December 4, 1902.*

[Four hours' duration with 2-inch forced draft, using Branch crude-oil burner, air.]

Time.	Pressure on oil system.	Draft pressures.							Smoke.	Revolutions of fan.	Oil burned per hour.	Feed water per hour.
		Fireroom.	Furnace.	Combustion chamber.	Tube chamber.		Above tubes, below drums.	Base of stack.				
					Front.	Back.						
	Lbs.										*Lbs.*	*Lbs.*
11 a. m....	30	2	1.6	1	1.10	0.95	—0.25	—0.42	.....	387	0	0
11.15 a. m.	30	2	1.6	1	1.05	.9	— .27	— .42	.....	378	......	......
11.30 a. m.	30	2	1.6	1	1.05	.9	— .26	— .42	0.75	382	......	......
11.45 a. m.	30	2	1.6	1	1.03	.9	— .27	— .42	.....	380	......	......
12 m......	30	2	1.6	1	1.03	.9	— .27	— .42	.....	383	1,722	16,876
12.15 p. m.	30	2	1.6	1	1.10	1	— .27	— .42	.....	384	......	......
12.30 p. m.	40	2	1.6	1	1	.9	— .27	— .42	1	383	......	......
12.45 p. m.	40	2	1.6	1	1.1	1	— .27	— .42	.....	385	......	......
1 p. m	40	2	1.6	1	1.1	1	— .27	— .42	.....	384	1,885	18,275
1.15 p. m..	40	2	1.6	1	1.1	1	— .27	— .42	.....	384	......	......
1.30 p. m..	40	2	1.6	1	1.1	1	— .27	— .42	1	385	......	......
1.45 p. m..	40	2	1.6	1	1.1	1	— .27	— .42	.....	388	......	......
2 p. m	40	2	1.6	1	1	1.03	— .26	— .42	.....	390	1,905	18,388
2.15 p. m..	40	2	1.6	1	1	1.02	— .27	— .42	.....	387	......	......
2.30 p. m..	40	2	1.6	1	1	1.02	— .27	— .42	.....	385	......	......
2.45 p. m..	40	2	1.6	1	1	1.02	— .27	— .42	.....	385	......	......
3 p. m	40	2	1.6	1	1	1.02	— .27	— .42	.....	385	1,728	17,036
Average ..	36.5	2	1.6	1	1.05	.974	— .268	— .42	.92	384	1,810	17,644

Deflectors were placed in the ash-pit openings to direct the entering air upward. Only four burners were used, the two side burners being idle. The feed water during the test was very muddy. There was a deposit of carbon 14 inches in diameter on the left side wall of the furnace.

Total pounds oil burned, 7,240.

Total pounds feed water, 70,575.

No. 27.—*Test of oil fuel in a Hohenstein water-tube marine boiler, December 5, 1902.*

[Five hours' duration with 2-inch forced draft, using Branch crude-oil burner, steam.]

Time.	Steam-pressure gauge.	Temperature of feed.	Calorimeter.			Height of water in gauge glass.	Temperature.				Steam pressure in Scotch boiler for burners.	Pressure on oil system.
			T_1.	T_2.	Q.		Air in fireroom.	Oil in weigh tank.	Steam for burner.	Gases at base of stack.		
	Lbs.	° *F.*	° *F.*	° *F.*		*Ins.*	° *F.*	° *F.*	° *F.*	° *F.*	*Lbs.*	*Lbs.*
11 a. m....	275	113	408	300	0. 979	1. 75	70	.....	370	.....	90	55
11.15 a. m.	275	100	408	301	. 980	2	70	.....	372	.....	89	55
11.30 a. m.	275	102	408	301	. 980	2	70	40	372	800	88	55
11.45 a. m.	275	108	408	301	. 980	1. 75	72	.....	374	.....	92	55
12 m......	280	93	406	300	. 980	1. 75	72	.....	378	.....	93	55
12.15 p. m.	274	100	408	301	. 980	1. 75	72	.....	376	.....	90	55
12.30 p. m.	275	100	408	301	. 980	1. 75	72	40	376	790	92	55
12.45 p. m.	274	102	408	300	. 979	2	73	.....	372	.....	94	55
1 p. m....	275	102	408	300	. 979	1. 75	72	.....	384	.....	90	55
1.15 p. m..	275	103	408	300	. 979	1. 75	72	.....	374	.....	92	55
1.30 p. m..	275	103	408	300	. 979	1. 75	72	40	374	810	90	55
1.45 p. m..	275	96	408	300	. 979	1. 75	72	.....	378	.....	90	55
2 p. m....	275	103	408	300	. 979	1. 75	72	.....	378	.....	90	55
2.15 p. m..	276	103	408	300	. 979	1. 75	71	.....	372	.....	90	55
2.30 p. m..	275	100	408	300	. 979	1. 50	73	40	382	850	91	55
2.45 p. m..	275	101	408	300	. 979	1. 75	73	.....	390	.....	90	55
3 p. m....	275	103	408	300	. 979	1. 75	73	.....	386	.....	90	55
3.15 p. m..	275	104	408	300	. 979	1. 75	73	.....	386	.....	90	55
3.30 p. m..	276	103	408	300	. 979	2	73	40	380	830	92	55
3.45 p. m..	275	100	408	300	. 979	1. 75	74	.....	382	.....	93	55
4 p. m....	278	104	409	300	. 979	1. 75	74	.....	378	.....	92	55
Average ..	275. 4	102. 05	.....	.....	. 9793	.....	72	40	379	816	90. 9	55

State of weather, wet and snowing.
Barometer at noon, 29.69 inches.
Draft opening into furnace, 660 square inches.
7 a. m., started fires under main boiler; 7.45 a. m., auxiliaries driven from main boiler; 8 a. m., 275 pounds pressure in main boiler; 10 a. m., started forced draft; 11 a. m., test begins.
Before beginning this test the boiler was blown down "half a glass."

No. 27.—*Test of oil fuel in a Hohenstein water-tube marine boiler, December 5, 1902.*

[Five hours' duration with 2-inch forced draft, using Branch crude-oil burner, steam.]

Time.	Draft pressures.						Smoke.	Revolutions of fan.	Oil burned per hour.	Steam for burners (feed water to special boiler) per hour.	Feed water per hour.
	Furnace.	Combustion chamber.	Tube chamber.		Above tubes, below drums.	Base of stack.					
			Front.	Back.							
									Lbs.	*Lbs.*	*Lbs.*
11 a. m....	1.55	1.0	0.95	0.9	—0.3	—0.4	.....	365	0	0	0
11.15 a. m.	1.6	1.0	1.0	1.0	— .25	— .34	.....	364	......	......	......
11.30 a. m.	1.6	1.0	1.0	1.0	— .25	— .34	.25	372	......	......	......
11.45 a. m.	1.6	1.0	1.0	1.0	— .25	— .36	.....	375	......	......	......
12 m......	1.6	1.0	1.0	1.0	— .30	— .4	.....	365	2,188	1,318	20,787
12.15 p. m.	1.6	1.0	1.0	1.0	— .25	— .45	.....	368	......	......	......
12.30 p. m.	1.6	1.0	1.0	1.0	— .25	— .45	.0	365	......	......	......
12.45 p. m.	1.6	1.0	1.0	1.0	— .25	— .45	.....	370	......	......	......
1 p. m	1.6	1.0	1.0	1.0	— .25	— .45	.....	368	2,075	1,056	20,774
1.15 p. m..	1.6	1.0	1.0	.95	— .25	— .45	.....	369	......	......	......
1.30 p. m..	1.6	1.0	1.0	.95	— .25	— .45	.25	370	......	......	......
1.45 p. m..	1.6	1.0	1.0	.95	— .25	— .45	.....	370	......	......	......
2 p. m	1.6	1.0	1.0	.95	— .25	— .45	.....	370	2,020	1,220	20,194
2.15 p. m..	1.6	1.0	1.0	.95	— .25	— .45	.....	369	......	......	......
2.30 p. m..	1.6	1.0	1.0	.95	— .25	— .45	1.0	370	......	......	......
2.45 p. m..	1.6	1.0	1.0	.95	— .25	— .45	.....	370	......	......	......
3 p. m	1.6	1.0	1.0	.95	— .27	— .45	.....	372	2,123	1,185	20,861
3.15 p. m..	1.6	1.0	1.0	.95	— .27	— .45	.....	370	......	......	......
3.30 p. m..	1.6	1.0	1.0	.95	— .27	— .45	.25	370	......	......	......
3.45 p. m..	1.6	1.0	1.0	.95	.27	— .45	.....	372	......	......	......
4 p. m	1.6	1.0	1.0	.95	— .27	— .45	.....	372	2,069	1,160	20,878
Average ..	1.6	1.0	1.0	.97	— .26	— .43	.35	369	2,095	1,188	20,699

The feed water used during test was very muddy.
Draft pressure in fireroom, 2 inches.
Total pounds oil burned, 10,475.
Total pounds steam for burners, 5,939.
Total pounds feed water, 103,494.

No. 28.—*Test of oil fuel in a Hohenstein water-tube marine boiler, December 6, 1902.*

[Two hours' duration with 2-inch forced draft, using Branch crude-oil burner, air.]

Time.	Steam pressure gauge.	Temperature of feed.	Calorimeter.			Height of water in gauge glass.	Temperature.				Revolutions of air compressor.	Pressure of air for burners.
			T_1.	T_2.	Q.		Air in fireroom.	Oil in weigh tank.	Air for burner.	Gases at base of stack.		
	Lbs.	° *F.*	° *F.*	° *F.*		*Ins.*	° *F.*	° *F.*	° *F.*	° *F.*		*Lbs.*
11 a. m....	275	100	408	296	0.977	1.75	68	.....	316	.....	74	49
11.15 a. m.	275	102	406	292	.975	1.75	68	.....	300	.....	74	49
11.30 a. m.	276	103	406	296	.977	1.75	70	31	314	750	75	49
11.45 a. m.	276	100	406	296	.977	2	70	.....	310	.....	76	49
12 m......	277	100	408	296	.977	1.75	70	.....	310	.....	75	49
12.15 p. m.	275	100	406	296	.977	2	72	.....	322	.....	75	49
12.30 p. m.	270	118	406	296	.977	1.75	72	31	394	715	75	49
12.45 p. m.	275	96	406	296	.977	1.75	72	.....	296	.....	75	49
12.55 p. m.	......	......	400	294	.979	1.75	72	.....	224	.....	......	.....
Average ..	274.9	102.4	.....	.....	.977	.....	70.4	31	310	733	75	49

State of weather, heavy mist, then clearing.
Barometer at noon, 30.36 inches.
Draft openings into furnace, 660 square inches until noon, then 672 square inches.

7 a. m., started fires under main boiler; 7.45 a. m., auxiliaries driven from main boiler; 8 a. m., 275 pounds pressure in main boiler; 10 a. m., started forced draft; 11 a. m., test begins.

No. 28.—*Test of oil fuel in a Hohenstein water-tube marine boiler, December 6, 1902.*

[Two hours' duration with 2-inch forced draft, using Branch crude-oil burner, air.]

Time.	Pressure on oil system.	Draft pressures.							Smoke.	Revolutions of fan.	Oil burned per hour.	Feed water per hour.
		Fireroom.	Furnace.	Combustion chamber.	Tube chamber.		Above tubes; below drums.	Base of stack.				
					Front.	Back.						
	Lbs.										*Lbs.*	*Lbs.*
11 a. m.	35	2	1.6	1	1	0.95	−0.27	−0.4	.....	372	0	0
11.15 a. m.	35	2	1.6	1	1	.95	− .27	− .38	.....	373	......	......
11.30 a. m.	35	2	1.6	1	1	.95	− .3	− .38	1	372	......	......
11.45 a. m.	35	2	1.6	1	1	.95	− .3	− .38	.....	370	......	......
12 m.	35	2	1.6	1	1	.95	− .3	− .38	.....	372	1,945	19,406
12.15 p. m.	35	2	1.6	1	1	.95	− .3	− .38	.....	368	......	......
12.30 p. m.	35	2	1.6	1	1	.95	− .3	− .38	.25	367	......	......
12.45 p. m.	35	2	1.6	1	1	.95	− .3	− .38	.....	367	......	......
12.55 p. m.	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	1,752	18,398
Average	35	2	1.6	1	1	.95	− .29	− .38	.63	370	1,848	18,902

Feed water very muddy. The boiler was blown down "half a glass" before beginning test. Also two of the burners were taken down and cleaned. They had become clogged with packing, probably from the gland on the oil regulating valve.

Test was stopped at 12.55 p. m. on account of accident to air compressor.

Total pounds oil burned, 3,697.

Total pounds feed water, 37,804.

No. 29.—*Test of oil fuel in a Hohenstein water-tube marine boiler, January 1, 1903.*

[Four hours' duration with 2-inch forced draft, using Best crude oil burner, steam.]

Time.	Steam pressure gauge.	Temperature of feed.	Calorimeter.			Height of water in gauge glass.	Temperature.					Steam pressure for burners (Scotch boiler).
			T₁.	T₂.	Q.		Inside.		Air in fireroom.	Steam for burner.	Gases at base of stack.	
							Dry.	Wet.				
	Lbs.	° *F.*	° *F.*	° *F.*	° *F.*	*Ins.*	° *F.*	° *F.*	° *F.*	° *F.*	° *F.*	*Lbs.*
5.45 p. m.	275	96	404	298	0.9795	2	.....	.....	76	426	....	90
6 p. m	275	100	404	290	.975	2	.....	.....	76	420	720	90
6.15 p. m.	275	96	404	290	.975	3	88	72	74	420	....	90
6.30 p. m.	275	90	404	292	.976	2	.....	.....	74	426	....	90
6.45 p. m.	275	100	402	288	.9745	2	.....	.....	74	430	....	90
7 p. m	275	92	402	288	.975	2	.....	.....	72	428	745	90
7.15 p. m.	275	92	402	290	.976	2	88.5	73.5	72	428	....	90
7.30 p. m.	275	94	402	290	.976	2	.....	.....	72	428	....	90
7.45 p. m.	275	102	402	290	.976	2	.....	.....	72	426	....	90
8 p. m	275	100	402	290	.976	2	.....	.....	72	426	760	90
8.15 p. m.	275	88	402	290	.976	2	85	72	70	432	....	90
8.30 p. m.	275	88	402	290	.976	2	.....	.....	68	432	....	90
8.45 p. m.	275	100	402	290	.976	2	.....	.....	68	432	....	90
9 p. m	275	92	402	290	.976	2	.....	.....	68	428	775	90
9.15 p. m.	275	94	402	290	.976	2	84	70.5	68	426	....	90
9.30 p. m.	275	92	402	290	.976	2	.....	.....	70	430	....	90
9.45 p. m.	275	92	402	290	.976	2	.....	.....	69	428	....	90
Average	275	94.6	.....	.....	.976	.....	86.4	72.0	71.47	427.4	750	90

State of weather, misty.
Barometer at noon, 30.3 inches.

Draft opening into furnace, 4 ◎ 3 ▭ = 776 square inches.

Boiler under 275 pounds from 11 a. m. until 12.15, when shut down on account of trouble with water gauge.
Blew down boiler 1 glass at 1 p. m.
4 p. m., forced draft put on. 4.45, started under full test conditions.

No. 29.—*Test of oil fuel in a Hohenstein water-tube marine boiler, January 1, 1903.*

[Four hours' duration with 2-inch forced draft, using Best crude oil burner, steam.]

Time.	Draft pressures.					Flue gases.			Revolutions of fan.	Oil burned per hour.	Steam for spraying (feed water to special boiler) per hour.	Feed water per hour.
	Combustion chamber.	Tube chamber.		Above tubes below drums.	Base of stack.	CO$_2$.	O.	CO.				
		Front.	Back.									
						P. ct.	*P. ct.*	*P. ct.*		*Lbs.*	*Lbs.*	*Lbs.*
5.45 p. m..	1.0	1.0	1.0	0.2	−0.4	......	......	......	386	......	......	......
6 p. m	1.0	1.0	1.0	.2	− .4	7.5	11.6	0.3	386	......	......	......
6.15 p. m..	1.0	1.0	1.0	.2	− .4	......	......	......	385	......	......	......
6.30 p. m..	1.0	1.0	1.0	.2	− .4	......	......	......	383	......	......	......
6.45 p. m..	1.0	1.0	1.0	.2	− .4	......	......	......	379	2,025	680	21,003
7 p. m	1.0	1.0	1.0	.2	− .4	6.8	12.0	.4	382	......	......	......
7.15 p. m..	1.0	1.0	1.0	.2	− .4	......	......	......	384	......	......	......
7.30 p. m..	1.0	1.0	1.0	.2	− .4	......	......	......	385	......	......	......
7.45 p. m..	1.0	1.0	1.0	.2	− .4	......	......	......	374	2,000	658	19,356
8 p. m	1.0	1.0	1.0	.2	− .4	6.4	12.2	.3	382	......	......	......
8.15 p. m..	1.0	1.0	1.0	.2	− .4	......	......	......	385	......	......	......
8.30 p. m..	1.0	1.0	1.0	.2	− .4	......	......	......	383	.....	......	......
8.45 p. m..	1.0	1.0	1.0	.2	− .4	......	......	......	384	2,089	628	20,547
9 p. m	1.0	1.0	1.0	.2	− .4	......	......	......	384	......	......	......
9.15 p. m..	1.0	1.0	1.0	.2	− .4	......	......	......	385	......	......	......
9.30 p. m..	1.0	1.0	1.0	.2	− .4	......	......	......	382	......	......	......
9.45 p. m..	1.0	1.0	1.0	.2	− .4	......	......	......	386	2,045	706	20,791
Average ..	1.0	1.0	1.0	.2	− .4	6.9	11.9	.33	383.3	2,040	668	20,424

5.45, test records assumed to begin, but had been taken from the start at 4.45. 9.45, test concluded.
Temperature of oil in weigh tank, 36° F.
Pressure on oil system, 30 pounds.
Draft pressure in fireroom, 2 inches.
Draft pressure at furnace, 1.5 inches.
Total pounds oil burned, 8,159.
Total pounds steam for spraying, 2,672.
Total pounds feed water, 81,697.

No. 30.—*Test of oil fuel in a Hohenstein water-tube marine boiler, January 3, 1903.*

[Six hours' duration with 1-inch forced draft, using Best crude-oil burner, steam.]

Time.	Steam pressure gauge.	Temperature of feed.	Calorimeter.			Height of water in gauge glass.	Temperature.					Steam pressure for burners.
							Inside.					
			T_1.	T_2.	Q.		Dry.	Wet.	Air in fireroom.	Steam for burner.	Gases at base of stack.	
	Lbs.	° *F.*	° *F.*	° *F.*		*Ins.*	° *F.*	° *F.*	° *F.*	° *F.*	° *F.*	*Lbs.*
11.30 a. m.	275	98	404	290	0.975	1.25	......	.....	80	410	.....	90
11.45 a. m.	275	110	404	290	.975	1.25	......	.....	82	410	.....	90
12 m......	275	98	404	292	.976	2.0	104	80	82	410	695	90
12.15 p. m.	275	110	404	292	.976	2.5	......	.....	82	412	.....	90
12.30 p. m.	275	118	404	292	.976	2.0	......	.....	82	410	.....	90
12.45 p. m.	273	93	404	292	.976	1.5	......	.....	84	406	.....	90
1 p. m.....	275	110	404	292	.976	1.75	104.75	80	84	412	700	90
1.15 p. m..	275	110	404	292	.976	1.5	......	.....	84	408	.....	90
1.30 p. m..	275	108	404	292	.976	1.5	......	.....	84	408	.....	90
1.45 p. m..	275	108	404	292	.976	1.5	......	.....	84	406	.....	90
2 p. m.....	275	102	404	292	.976	1.75	105	82	84	408	680	90
2.15 p. m..	275	100	404	292	.976	1.75	......	.....	84	408	.....	90
2.30 p. m..	274	104	404	292	.976	1.5	......	.....	85	408	.....	90
2.45 p. m..	270	96	404	292	.976	2.0	......	.....	84	410	.....	90
3 p. m.....	275	118	404	292	.976	1.5	103	79	84	404	680	90
3.15 p. m..	275	115	404	292	.976	1.5	......	.....	84	406	.....	90
3.30 p. m..	275	115	404	292	.976	1.75	......	.....	84	398	.....	90
3.45 p. m..	275	118	404	292	.976	2.0	......	.....	84	398	.....	90
4 p. m.....	275	100	404	292	.976	1.5	106.5	82	84	406	670	90
4.15 p. m..	275	102	404	292	.976	1.5	......	.....	84	408	.....	90
4.30 p. m..	275	108	404	292	.976	2.0	......	.....	84	404	.....	90
4.45 p. m..	275	100	404	292	.976	2.0	......	.....	84	400	.....	90
5 p. m.....	275	108	404	292	.976	1.5	112	84	84	410	700	90
5.15 p. m..	275	98	404	292	.976	1.5	......	.....	84	410	.....	90
5.30 p. m..	275	110	404	292	.976	1.5	......	.....	84	408	.....	90
Average ..	274.68	106.28	.....	.....	.976	.....	108.8	81.1	83.56	407.1	687.5	90

State of weather, overcast; heavy fog.
Barometer at noon, 29.63 inches.
Draft opening into furnace, 4 ⊙ 3 ▭ = 776 square inches.
Started fires in main boiler at 7 a. m.; 275 pounds pressure in main boiler at 8 a. m.; started forced draft at 9.30 a. m.; started test records at 11.30 a. m.
Temperature of oil in weigh tank, 32° F.

No. 30.—*Test of oil fuel in a Hohenstein water-tube marine boiler, January 3, 1903.*

[Six hours' duration with 1-inch forced draft, using Best crude-oil burner, steam.]

Time.	Draft pressures.					Flue gases.			Revolutions of fan.	Oil burned per hour.	Steam for spraying per hour.	Feed water per hour.
	Combustion chamber.	Tube chamber. Front.	Tube chamber. Back.	Above tubes below drums.	Base of stack.	CO$_2$.	O.	CO.				
						P. ct.	*P. ct.*	*P. ct.*		*Lbs.*	*Lbs.*	*Lbs.*
11.30 a. m.	0.47	0.45	0.45	−0.05	−0.5	....	......	......	282	0	0	0
11.45 a. m.	.47	.45	.45	− .05	− .5	....	......	......	283	......	......	......
12 m.	.47	.45	.45	− .05	− .5	7.9	10.1	0	282	......	......	......
12.15 p. m.	.47	.45	.45	− .05	− .5	....	......	......	282	......	......	......
12.30 p. m.	.47	.45	.45	− .05	− .5	....	......	......	282	1,807	793	19,806
12.45 p. m.	.47	.45	.45	− .05	− .5	....	......	......	281	......	......	......
1 p. m.	.47	.45	.45	− .05	− .5	7.8	10.0	0.3	282	......	......	......
1.15 p. m.	.47	.45	.45	− .05	− .5	....	......	......	282	......	......	......
1.30 p. m.	.47	.45	.45	− .05	− .5	....	......	......	282	1,771	830	18,768
1.45 p. m.	.47	.45	.45	− .05	− .5	....	......	......	282	......	......	......
2 p. m.	.47	.45	.45	− .05	− .5	7.7	10.7	0	282	......	......	......
2.15 p. m.	.47	.45	.45	− .05	− .5	....	......	......	282	......	......	......
2.30 p. m.	.47	.45	.45	− .05	− .5	....	......	......	282	1,732	763	18,663
2.45 p. m.	.47	.45	.45	− .05	− .5	....	......	......	283	......	......	......
3 p. m.	.47	.45	.45	− .05	− .5	7.6	11.0	0	283	......	......	......
3.15 p. m.	.47	.45	.45	− .05	− .5	....	......	......	282	......	......	......
3.30 p. m.	.47	.45	.45	− .05	− .5	....	......	......	283	1,603	806	17,229
3.45 p. m.	.47	.45	.45	− .05	− .5	....	......	......	282	......	......	......
4 p. m.	.47	.45	.45	− .05	− .5	8.0	10.7	0	283	......	......	......
4.15 p. m.	.47	.45	.45	− .05	− .5	....	......	......	285	......	......	......
4.30 p. m.	.47	.45	.45	− .05	− .5	....	......	......	283	1,600	785	17,010
4.45 p. m.	.47	.45	.45	− .05	− .5	....	......	......	283	......	......	......
5 p. m.	.47	.45	.45	− .05	− .5	....	......	......	283	......	......	......
5.15 p. m.	.47	.45	.45	− .05	− .5	....	......	......	283	......	......	......
5.30 p. m.	.47	.45	.45	− .05	− .5	....	......	......	283	1,650	810	17,925
Average	.47	.45	.45	− .05	− .5	7.8	10.5	.06	282.5	1,694	798	18,233

Pressure on oil system, 30 pounds.
Draft pressure in fireroom, 1 inch.
Draft pressure at furnace, 0.8 inch.
Total pounds oil burned, 10,163.
Total pounds steam for spraying, 4,787.
Total pounds feed water, 109,401.

No. 31.—*Test of oil fuel in a Hohenstein water-tube marine boiler, January 5, 1903.*

[Four hours' duration with 3-inch forced draft, using Best crude oil burner, under steam.]

Time.	Steam pressure by gauge.	Temperature of feed water.	Calorimeter.			Height of water in gauge glass.	Temperature.				
							Inside.				
			T₁.	T₂.	Q.		Dry.	Wet.	Air in fireroom.	Steam for burner.	Gases at base of stack.
	Lbs.	° *F.*	° *F.*	° *F.*	° *F.*	*Ins.*	° *F.*	° *F.*	° *F.*	° *F.*	
3.45 p. m..	275	110	400	286	0.9740	1.5	......	......	76	430	.....
4 p. m	275	121	402	288	.9745	2.0	......	......	77	430	720
4.15 p. m..	275	100	404	288	.9735	1.5	94	72.5	77	424	.....
4.30 p. m..	275	98	402	288	.9745	1.5	......	......	78	438	.....
4.45 p. m..	273	94	402	288	.9745	1.5	......	......	77	420	.....
5 p. m	275	90	402	288	.9745	2.0	......	......	78	442	790
5.15 p. m..	275	90	404	288	.9735	1.75	104.5	81	78	456	.....
5.30 p. m..	275	100	404	288	.9735	1.75	......	......	78	450	.....
5.45 p. m..	275	96	402	288	.9745	1.5	......	......	78	446	.....
6 p. m	275	85	400	288	.9740	2.0	.. ...	......	78	448	810
6.15 p. m..	275	94	404	288	.9735	2.5	104	80	77	442	.....
6.30 p. m..	275	96	402	288	.9745	1.75	......	......	77	450	.....
6.45 p. m..	274	94	404	288	.9735	1.5	......	......	78	450	.....
7 p. m	275	94	402	288	.9745	2.0	......	......	78	454	840
7.15 p. m..	275	98	402	288	.9745	1.5	105	81	77	456	.....
7.30 p. m..	275	98	402	288	.9745	1.5	......	......	77	450	.....
7.45 p. m..	275	98	402	288	.9745	1.5	......	......	77	456	.....
Average ..	274.7	97.4	......	.....	.9741	.....	101.8	78.6	77.5	443.5	790

State of weather.

Barometer at noon, 29.85 inches.

Draft opening into furnace equal 776 square inches.

Test starts at 3.45 p. m.; lighted fires at 1 p. m.; 275 pounds pressure at 1.30 p. m.; 3-inch forced draft at 2 p. m.

Boiler had been under steam during forenoon and was warm at 3 p. m. Nipple for feed pump pressure gauge burst; was replaced, stopping pump without shutting off oil.

No. 31.—*Test of oil fuel in a Hohenstein water-tube marine boiler, January 5, 1903.*

[Four hours' duration with 3-inch forced draft, using Best crude oil burner, under steam.]

Time.	Pressure on oil system.	Draft pressures.				Flue gases.			Revolutions of fans.	Oil burned per hour.	Steam for spraying per hour.	Feed water per hour.
		Furnace.	Tube chambers.		Above tubes, below drums.	CO_2.	O.	CO_1.				
			Front.	Back.								
						P. ct.	*P. ct.*	*P. ct.*		*Lbs.*	*Lbs.*	*Lbs.*
3.45 p. m..	30	2.45	1.6	1.5	0.5	.....	.....	.....	448	.....	.....	.....
4 p. m....	30	2.40	1.6	1.5	.5	6.4	10.0	1.6	448	.....	.....	.....
4.15 p. m..	33	2.40	1.6	1.5	.5	.....	.....	.....	449	.....	.....	.....
4.30 p. m..	33	2.40	1.6	1.5	.5	.....	.....	.....	450	.....	.....	.....
4.45 p. m..	33	2.40	1.6	1.5	.5	.....	.....	.....	450	2,277	823	22,812
5 p. m....	33	2.40	1.6	1.5	.5	8.0	9.0	.4	449	.....	.....	.....
5.15 p. m..	33	2.40	1.6	1.5	.5	.....	.....	.....	448	.....	.....	.....
5.30 p. m..	33	2.40	1.6	1.5	.5	.....	.....	.....	448	.....	.....	.....
5.45 p. m..	33	2.40	1.6	1.5	.5	.....	.....	.....	448	2,521	850	26,546
6 p. m....	33	2.40	1.6	1.5	.5	.....	.....	.....	449	.....	.....	.....
6.15 p. m..	33	2.40	1.6	1.5	.5	.....	.....	.....	448	.....	.....	.....
6.30 p. m..	33	2.40	1.6	1.5	.5	.....	.....	.....	448	.....	.....	.....
6.45 p. m..	33	2.40	1.6	1.5	.5	.....	.....	.....	448	2,560	801	25,882
7 p. m....	33	2.40	1.6	1.5	.5	7.5	11.1	.1	448	.....	.....	.....
7.15 p. m..	33	2.40	1.6	1.5	.5	.....	.....	.....	448	.....	.....	.....
7.30 p. m..	33	2.40	1.6	1.5	.5	.....	.....	.....	448	.....	.....	.....
7.45 p. m..	33	2.40	1.6	1.5	.5	.....	.....	.....	449	2,582	825	27,002
Average ..	33	2.40	1.6	1.5	.5	7.3	10.0	.7	448.5	2,485	824.2	25,560

Temperature of oil in weigh tank, 40° F.
Steam pressure for boilers, 90 pounds.
Draft pressure in fireroom, 3 inches.
Draft pressure in combustion chamber, 1.6 inches.
Draft pressure at base of stack, −0.3 inch.
Total pounds oil burned, 9,940.
Total pounds steam for spraying, 3,299.
Total pounds feed water, 102,242.

No. 32.—*Test of oil fuel in a Hohenstein water-tube marine boiler, January 10, 1903.*

[Eight hours' duration with natural draft, using Harvey system, compressed air.]

Time.	Steam pressure, gauge.	Temperature of feed.	Calorimeter.			Height of water in gauge glass.	Temperature.					Revolutions of air compressor.
							Inside.					
			T_1.	T_2.	Q.		Dry.	Wet.	Air in fireroom.	Air for burner.	Gases at base of stack.	
	Lbs.	° *F.*	° *F.*	° *F.*		*Ins.*	° *F.*	° *F.*	° *F.*	° *F.*	° *F.*	
10.30 a. m.	280	96	402	298	0.9805	2.5	.....	.....	72	366	.....	26
10.45 a. m.	276	120	402	300	.9815	2.5	.....	.....	76	358	.....	26
11 a. m....	278	144	402	298	.9805	2.5	99	81	80	354	570	27
11.15 a. m.	276	128	404	304	.9830	1.5	.....	.....	82	342	.....	27
11.30 a. m.	275	120	408	306	.9825	2.5	.....	.....	83	338	.....	27
11.45 a. m.	275	120	408	304	.9815	2	.....	.....	84	340	.....	27
12 m......	273	120	408	306	.9825	2.5	101.5	79.5	84	340	550	27
12.15 p. m.	275	128	404	306	.9840	1.5	.....	.....	86	338	.....	27
12.30 p. m.	278	120	408	308	.9835	2.5	.....	.....	88	336	.....	27
12.45 p. m.	275	120	406	306	.9830	1.5	.....	.....	88	340	.....	27
1 p. m....	278	118	408	306	.9825	1.5	116.5	88.5	88	338	575	27
1.15 p. m..	275	114	404	306	.9820	1.5	.....	.....	86	344	.....	27
1.30 p. m..	275	110	408	306	.9825	1.5	.....	.....	84	344	.....	27
1.45 p. m..	277	110	406	308	.9845	1.5	.....	.....	84	344	.....	27
2 p. m....	278	100	408	308	.9835	2.5	110	86	84	350	575	27
2.15 p. m..	275	108	406	308	.9845	2.5	.....	.....	86	358	.....	27
2.30 p. m..	280	112	402	306	.9830	2.5	.....	.....	86	358	.....	27
2.45 p. m..	275	110	402	306	.9830	2.5	.....	.....	90	350	.....	27
3 p. m....	275	120	404	308	.9850	2.5	119.5	87	90	344	555	27
3.15 p. m..	275	120	404	308	.9850	2.5	.....	.....	90	332	.....	27
3.30 p. m..	275	120	408	308	.9835	3	.....	.....	88	332	.....	27
3.45 p. m..	275	120	409	308	.9835	2.5	.....	.....	88	322	.....	27
4 p. m....	275	118	410	310	.9840	2.5	121	89	88	330	560	27
4.15 p. m..	276	120	408	310	.9845	2.5	.....	.....	90	340	.....	27
4.30 p. m..	276	118	408	310	.9845	2.5	.....	.....	90	342	.....	27
4.45 p. m..	275	120	408	310	.9845	2	.....	.....	88	334	.....	27
5 p. m....	275	120	410	308	.9835	2.5	121	89	88	334	565	27
5.15 p. m..	276	122	406	308	.9845	3	.....	.....	88	340	.....	27
5.30 p. m..	280	120	406	308	.9845	2.5	.....	.....	88	342	.....	27
5.45 p. m..	278	120	406	308	.9845	2.5	.....	.....	88	342	.....	27
6 p. m....	276	120	406	308	.9845	2.5	118.5	87.5	88	336	570	27
6.15 p. m..	275	128	406	308	.9845	2.5	.....	.....	88	336	.....	27
6.30 p. m..	276	120	406	308	.9845	2.5	.....	.....	86	338	.....	27
Average ..	276.1	118.1	.....	.....	.9835	.....	113.4	85.9	86	341.9	565	27

State of weather, clear, dry, and cold.
Barometer at noon, 30.17 inches.
Draft opening into furnace 3 □ = 776 square inches.
Air conduits of "Best" system in use.

This run was made with the front row of baffling on the 4-inch tubes removed, leaving an opening of 8 inches extending the width of the furnace.

Test starts at 10.30 a. m.; fires were lighted at 5.55 a. m.; boiler connected with auxiliaries at 7 a. m. Shut down from 8.05 until 8.55 on account of disablement of safety valve on auxiliary line.

No. 32.—*Test of oil fuel in a Hohenstein water-tube marine boiler, January 10, 1903.*

[Eight hours' duration with natural draft, using Harvey system, compressed air.]

Time.	Draft pressures.						Flue gases.			Oil burned per hour.	Feed water per hour.
	Furnaces.	Combustion chamber.	Tube chamber.		Above tubes, below drums.	Base of stack.	CO_2.	O.	CO_1.		
			Front.	Back.							
							P. ct.	*P. ct.*	*P. ct.*	*Lbs.*	*Lbs.*
10.30 a. m.	0.16	0.26	0.24	0.25	0.43	0.55	.....	.....	.....	......	......
10.45 a. m.	.16	.26	.24	.25	.43	.55	.....	.....	.....	......	......
11 a. m.	.16	.26	.24	.25	.43	.55	6.5	11.7	0	......	......
11.15 a. m.	.16	.26	.24	.25	.43	.55	.....	.....	.....	......	......
11.30 a. m.	.18	.26	.24	.25	.43	.55	.....	.....	.....	902	11,308
11.45 a. m.	.18	.26	.24	.25	.43	.55	.....	.....	.....	......	......
12 m	.18	.26	.24	.25	.43	.55	.....	.....	.....	......	......
12.15 p. m.	.18	.26	.24	.25	.43	.55	.....	.....	.....	......	......
12.30 p. m.	.18	.26	.24	.25	.43	.55	.....	.....	.....	869	9,325
12.45 p. m.	.18	.26	.24	.25	.43	.55	.....	.....	.....	......	......
1 p. m.	.18	.26	.24	.25	.43	.55	6.2	12.6	0.1	......	......
1.15 p. m.	.17	.24	.22	.23	.42	.53	.....	.....	.....	......	......
1.30 p. m.	.17	.24	.22	.23	.42	.52	.....	.....	.....	987	12,097
1.45 p. m.	.17	.24	.22	.23	.41	.52	.....	.....	.....	......	......
2 p. m.	.17	.24	.22	.23	.41	.52	.....	.....	.....	......	......
2.15 p. m.	.17	.24	.22	.23	.41	.52	.....	.....	.....	......	......
2.30 p. m.	.17	.24	.22	.23	.41	.52	.....	.....	.....	1,072	13,073
2.45 p. m.	.17	.24	.22	.23	.38	.52	.....	.....	.....	......	......
3 p. m.	.17	.24	.22	.24	.39	.52	6.8	11.4	0	......	......
3.15 p. m.	.17	.24	.22	.24	.39	.52	.....	.....	.....	......	......
3.30 p. m.	.17	.24	.22	.24	.39	.52	.....	.....	.....	949	11,882
3.45 p. m.	.17	.24	.22	.24	.40	.52	.....	.....	.....	......	......
4 p. m.	.17	.24	.22	.24	.40	.53	.....	.....	.....	......	......
4.15 p. m.	.17	.24	.22	.24	.40	.53	.....	.....	.....	......	......
4.30 p. m.	.17	.24	.22	.24	.40	.53	.....	.....	.....	949	11,586
4.45 p. m.	.17	.24	.22	.24	.40	.53	.....	.....	.....	......	......
5 p. m.	.17	.24	.22	.24	.40	.53	6.5	12.2	0	......	......
5.15 p. m.	.17	.24	.22	.24	.40	.53	.....	.....	.....	......	......
5.30 p. m.	.17	.24	.22	.24	.40	.53	.....	.....	.....	986	11,749
5.45 p. m.	.17	.24	.22	.24	.40	.53	.....	.....	.....	......	......
6 p. m.	.17	.24	.22	.24	.40	.53	.....	.....	.....	......	......
6.15 p. m.	.17	.24	.22	.24	.40	.53	.....	.....	.....	......	......
6.30 p. m.	.17	.24	.22	.24	.40	.53	.....	.....	.....	922	11,879
Average	.17	.243	.226	.241	.411	.534	6.5	12.2	0.02	954.3	11,612

Boiler was washed out and tubes cleaned of soot before the run.
Furnace as with "Best" burners.
Temperature of oil in weigh tank, 30° F.
Air pressure at compressor, 23 pounds.
Pressure on carburetter system, 18 pounds.
Total pounds oil burned, 7,636.
Total pounds feed water, 92,899.

No. 33.—*Test of oil fuel in a Hohenstein water-tube marine boiler, January 12, 1903.*

[Eight hours' duration with natural draft, using Harvey system, compressed air.]

Time.	Steam-pressure gauge.	Temperature of feed.	Calorimeter.			Height of water in gauge glass.	Temperature.					
			T_1.	T_2.	Q.		Inside.		Air in fireroom.	Oil in weigh tank.	Air for burner.	Gases at base of stack.
							Dry.	Wet.				
	Lbs.	° *F.*	° *F.*	° *F.*		*In.*	° *F.*	° *F.*	° *F.*	° *F.*	° *F.*	° *F.*
12 a. m ...	275	90	408	306	0.9825	2.5	.....	.....	56	28	300	......
12.15 p. m.	275	120	408	308	.9835	2.5	.....	.....	58	28	300	......
12.30 p. m.	285	120	408	308	.9835	2.5	80.5	72.5	60	28	300	565
12.45 p. m.	284	112	408	308	.9835	2.5	.....	.....	60	28	306	......
1 p. m....	275	120	408	308	.9835	3	.....	.....	60	28	294	......
1.15 p. m .	275	120	408	308	.9835	2	.....	.....	60	28	292	......
1.30 p. m .	275	120	408	308	.9835	2	76	73	60	28	294	540
1.45 p. m .	275	120	408	306	.9825	2.5	.....	.....	60	28	294	......
2 p. m....	275	120	408	304	.9815	2.5	.....	.....	60	28	292	......
2.15 p. m .	280	120	408	306	.9825	2.5	.....	.....	60	28	294	......
2.30 p. m .	275	120	408	306	.9825	2.5	100.5	82	62	28	296	520
2.45 p. m .	275	120	408	306	.9825	2	.....	.....	62	28	298	......
3 p. m....	275	120	408	306	.9825	2.5	.....	.....	62	24	300	......
3.15 p. m .	275	120	408	306	.9825	2.5	.....	.....	62	24	302	......
3.30 p. m .	275	119	408	306	.9825	2.5	103.5	86	62	24	300	525
3.45 p. m .	275	117	408	306	.9825	2	.....	.....	62	24	296	......
4 p. m....	275	120	408	306	.9825	2.5	.....	.....	58	24	290	......
4.15 p. m .	270	118	408	306	.9825	1.5	.....	.....	61	24	286	......
4.30 p. m .	280	120	404	304	.9830	1.5	99	80	60	24	286	515
4.45 p. m .	275	120	404	304	.9830	1.75	.....	.....	60	24	284	......
5 p. m....	275	118	406	306	.9830	2.5	.....	.....	58	24	280	......
5.15 p. m .	275	120	400	306	.9855	1.5	.....	.....	56	24	280	......
5.30 p. m .	275	120	406	306	.9830	1.5	94.5	79.5	58	24	278	550
5.45 p. m .	275	120	404	306	.9840	1	.....	.....	58	24	282	......
6 p. m....	273	118	406	306	.9830	2.5	.....	.....	58	24	284	......
6.15 p. m .	275	120	406	306	.9830	2	.....	.....	58	24	286	......
6.30 p. m .	275	118	406	306	.9830	2	83.5	70.5	56	24	284	555
6.45 p. m .	275	115	402	304	.9835	2.5	.....	.....	54	24	300	......
7 p. m....	275	104	404	306	.9840	2.5	.....	.....	54	24	310	......
7.15 p. m .	276	120	404	306	.9840	1.5	.....	.....	55	24	308	......
7.30 p. m .	278	120	404	306	.9840	1.5	84	71.5	54	24	302	550
7.45 p. m .	275	122	406	306	.9830	1.5	.....	.....	54	24	306	......
8 p. m....	276	118	400	308	.9870	2.5	.....	.....	56	24	310	......
Average ..	276	118	.....	.....	.9832	.....	90.2	76.8	58.6	25.4	294.4	540.2

State of weather, clear and cold.

Barometer at noon, 30.04 inches.

Draft opening into furnace, 752 square inches; same as on 10th, except that both end conduits (Best system) were blanked off.

Before this run baffling was restored to the normal condition.

Nozzles of $\frac{5}{16}$-inch bore were substituted for those on the burners used on the 10th.

Test starts at noon: Started fires at 6.30 a. m.; 275 pounds pressure at 7.45 a. m.

From 7.45 until 10.45 fires were put out three times, aggregating 70 minutes, for repairs to reducing valve.

No. 33.—*Test of oil fuel in a Hohenstein water-tube marine boiler, January 12, 1903.*

[Eight hours' duration with natural draft, using Harvey system, compressed air.]

Time.	Pressure on Carburetter system.	Draft pressures.						Flue gases.			Oil burned per hour.	Feed water per hour.
		Furnace.	Combustion chamber.	Tube chamber.		Above tubes below drums.	Base of stack.	CO$_2$.	O.	CO$_1$.		
				Front.	Back.							
								P. ct.	*P. ct.*	*P. ct.*	*Lbs.*	*Lbs.*
12 a. m	15	0.15	0.25	0.23	0.25	0.4	0.53					
12.15 p. m.	15	.14	.25	.23	.25	.4	.52					
12.30 p. m.	15	.15	.25	.23	.25	.4	.52	6.7	11.3	0.1		
12.45 p. m.	15	.15	.25	.23	.25	.4	.52					
1 p. m	16	.15	.25	.23	.25	.4	.52				996	12,395
1.15 p. m	15	.15	.25	.23	.25	.4	.52					
1.30 p. m	15	.155	.25	.23	.25	.4	.52					
1.45 p. m	15	.14	.23	.21	.23	.37	.5					
2 p. m	15	.14	.23	.21	.23	.37	.5				920	11,066
2.15 p. m	15	.15	.25	.23	.25	.35	.49					
2.30 p. m	15	.15	.25	.23	.25	.36	.48	6	12	.1		
2.45 p. m	18	.15	.25	.23	.25	.36	.48					
3 p. m	18	.14	.23	.21	.23	.35	.48				900	11,182
3.15 p. m	18	.14	.23	.21	.23	.35	.48					
3.30 p. m	15	.14	.23	.21	.23	.35	.48					
3.45 p. m	17	.14	.23	.21	.23	.36	.5					
4 p. m	15	.14	.23	.21	.23	.36	.5				978	11,785
4.15 p. m	15	.14	.23	.21	.23	.36	.5					
4.30 p. m	15	.14	.23	.21	.23	.36	.5	6.5	12.3	.2		
4.45 p. m	15	.14	.23	.21	.23	.36	.5					
5 p. m	16	.14	.23	.21	.23	.36	.5				843	10,387
5.15 p. m	15	.15	.25	.23	.25	.39	.51					
5.30 p. m	15	.15	.25	.23	.25	.39	.51	6	13.2	0		
5.45 p. m	15	.15	.25	.23	.25	.39	.51					
6 p. m	15	.15	.25	.23	.25	.39	.51				859	11,125
6.15 p. m	15	.15	.25	.23	.25	.39	.51					
6.30 p. m	15	.16	.25	.23	.25	.39	.51					
6.45 p. m	18	.15	.25	.23	.25	.39	.51					
7 p. m	18	.15	.25	.23	.25	.39	.51				963	11,456
7.15 p. m	18	.15	.25	.23	.25	.39	.51					
7.30 p. m	19	.15	.25	.23	.25	.39	.51					
7.45 p. m	20	.15	.25	.23	.25	.39	.51					
8 p. m	20	.15	.25	.23	.25	.39	.51				903	11,404
Average	16.1	.147	.243	.223	.243	.38	.52	6.3	12.2	.1	920.2	11,350

In the "Harvey system" the burner employed appears to be faulty in design. In it the oil and spraying agent are admitted in the same direction and with the same pressure, so that there is very little spraying effect.

The so-called "Carburetter" serves only to heat the air and oil, which could probably be accomplished in a much simpler installation.

Revolutions of air compressor, 34.

Air pressure at air compressor, 23 pounds.

Total pounds oil burned, 7,362.

Total pounds feed water, 90,800.

No. 34.—*Test of oil fuel in a Hohenstein water-tube marine boiler, January 15, 1903.*

[Eight hours' duration with natural draft, using Best burner, with air.]

Time.	Steam pressure gauge.	Temperature of feed.	Calorimeter.			Gauge glass.	Temperature.					Revolutions of air compressor.
							Inside.					
			T_1.	T_2.	Q.		Dry.	Wet.	Air in fireroom.	Oil in weigh tank.	Air for burner.	
	Lbs.	° *F.*	° *F.*	° *F.*		*Ins.*	° *F.*	° *F.*	° *F.*	° *F.*	° *F.*	
10 a. m....	275	120	404	306	0.9840	1.5	.....	.....	67	37	308	67
10.15 a. m.	280	120	402	306	.9850	1.5	.....	.....	72	37	292	67
10.30 a. m.	275	117	402	304	.9836	1.5	91	79½	72	37	290	67
10.45 a. m.	275	119	406	306	.9830	1	.....	.....	72	37	288	67
11 a. m....	275	120	402	306	.9850	1.5	.....	.....	70	37	294	67
11.15 a. m.	275	120	404	306	.9840	1	.....	.....	70	37	290	67
11.30 a. m.	280	118	402	306	.8850	1	104	85	70	37	292	67
11.45 a. m.	275	120	404	306	.9840	1.5	.....	.....	70	37	290	67
12 m......	275	117	406	304	.9820	1.5	.....	.....	70	37	286	67
12.15 p. m.	275	118	406	304	.9820	1.5	.....	.....	71	37	284	67
12.30 p. m.	278	120	404	306	.9840	1.5	.....	.....	71	37	290	67
12.45 p. m.	275	120	406	306	.9830	1.5	.....	.....	73	37	290	67
1 p. m	273	120	404	304	.9827	1.5	.....	.....	74	37	290	67
1.15 p. m..	275	120	406	306	.9830	1.5	.....	.....	76	37	274	67
1.30 p. m..	275	120	402	306	.9850	1	112	89	74	37	294	68
1.45 p. m..	275	120	406	306	.9830	1.5	.....	.....	76	37	302	67
2 p. m	278	118	404	306	.9840	1.5	.....	.....	74	37	300	67
2.15 p. m..	276	122	404	306	.9840	1.5	.....	.....	76	37	302	67
2.30 p. m..	275	120	404	306	.9840	1.5	104	86	82	37	300	67
2.45 p. m..	278	118	404	306	.9840	1.5	.....	.....	84	37	302	67
3 p. m	278	120	404	306	.9840	1.5	.....	.....	84	37	302	67
3.15 p. m..	274	120	402	306	.9850	1	.....	.....	76	37	296	67
3.30 p. m..	273	116	401	304	.9840	1.25	103½	82½	76	37	284	67
3.45 p. m..	275	120	401	304	.9840	1.5	.....	.....	76	37	280	67
4 p. m	275	120	401	304	.9840	1.5	.....	.....	76	37	280	67
4.15 p. m..	278	120	401	304	.9840	1	.....	.....	74	37	276	67
4.30 p. m..	275	116	401	304	.9840	1	101	81½	74	37	280	67
4.45 p. m..	270	110	404	304	.9827	1.5	.....	.....	74	37	280	67
5 p. m	275	120	404	304	.9827	1.5	.....	.....	74	37	278	67
5.15 p. m..	280	110	402	304	.9835	1.5	.....	.....	70	37	278	67
5.30 p. m..	275	118	402	304	.9835	1.5	107	83	68	37	276	67
5.45 p. m..	278	120	402	304	.9835	1.5	.....	.....	66	37	274	68
6 p. m	270	116	402	304	.9835	1.5	.....	.....	72	37	272	68
Average ..	275.6	118.6	.....	.....	.9837	.....	.....	.....	73.4	37	288.3	67

Barometer at noon, 30.03 inches.
Lighted fires at 5 a. m.; 275 pounds pressure at 6.20 a. m.; test starts at 10 a. m.
Test was delayed by ice in circulating water pipe of air pump.
Air pressure of 70 pounds was designated by Best representative.
Weather, cool and clear.

No. 34.—*Test of oil fuel in a Hohenstein water-tube marine boiler, January 15, 1903.*

[Eight hours' duration with natural draft, using Best burner, with air.]

Time.	Draft pressures.						Flue gases.			Smoke.	Oil burned per hour.	Feed water per hour.
			Tube chamber.									
	Furnace.	Combustion chamber.	Front.	Back.	Above tubes below drums.	Base of stack.	CO_2.	O.	CO.			
							P. ct.	*P. ct.*	*P. ct.*		*Lbs.*	*Lbs.*
10 a. m.	0.13	0.21	0.19	0.21	0.37	0.51						
10.15 a. m.	.12	.20	.18	.20	.38	.52						
10.30 a. m.	.11	.18	.16	.18	.38	.49	8	10.8	0.4	¼		
10.45 a. m.	.11	.18	.16	.18	.38	.49						
11 a. m.	.11	.18	.16	.18	.38	.49					1,098	12,749
11.15 a. m.	.11	.24	.16	.18	.38	.49						
11.30 a. m.	.15	.24	.22	.24	.39	.53				¼		
11.45 a. m.	.15	.24	.22	.24	.39	.53						
12 m.	.15	.24	.22	.24	.39	.53					1,163	13,343
12.15 p. m.	.15	.24	.22	.24	.39	.53						
12.30 p. m.	.15	.24	.22	.24	.39	.53	7.9	10.1	.5	½		
12.45 p. m.	.15	.24	.22	.24	.39	.53						
1 p. m.	.15	.24	.22	.24	.39	.53					1,134	13,351
1.15 p. m.	.15	.24	.22	.24	.39	.53						
1.30 p. m.	.14	.24	.22	.24	.39	.55				¾		
1.45 p. m.	.13	.24	.22	.24	.39	.56						
2 p. m.	.12	.24	.22	.24	.39	.56					1,215	14,336
2.15 p. m.	.12	.24	.22	.24	.39	.56						
2.30 p. m.	.12	.24	.22	.24	.39	.56	8.5	9.5	.8	¼		
2.45 p. m.	.13	.24	.22	.24	.41	.58						
3 p. m.	.13	.24	.22	.24	.41	.58					1,202	14,226
3.15 p. m.	.15	.24	.22	.24	.41	.58						
3.30 p. m.	.15	.26	.24	.25	.41	.55				¼		
3.45 p. m.	.15	.26	.24	.25	.42	.55						
4 p. m.	.15	.26	.24	.25	.42	.55					1,083	13,241
4.15 p. m.	.15	.26	.24	.26	.41	.55						
4.30 p. m.	.15	.26	.24	.26	.41	.55	8	12.5	0	0		
4.45 p. m.	.15	.26	.24	.26	.41	.55						
5 p. m.	.14	.25	.23	.25	.40	.56					1,101	13,138
5.15 p. m.	.15	.26	.24	.26	.41	.55						
5.30 p. m.	.15	.26	.24	.26	.41	.55				¼		
5.45 p. m.	.15	.26	.24	.26	.41	.55						
6 p. m.	.15	.26	.24	.26	.41	.55					1,072	12,466
Average	.138	.238	.217	.236	.393	.54					1,136	13,356

Air openings into furnace: 10 until 3 p. m., 3 ▭ × 4 ⊙ (air ducts open) until 11, when closed by inclined asbestos sheets until 2, after which they were left open. From 3 p. m. to 5.30, 3 ▭ + 4 ⊙ (air ducts open).

Air pressure on burner, 70 pounds.

Pressure on oil system, 25 pounds.

Total pounds oil burned, 9,068.

Total pounds feed water, 106,850.

No. 35.—*Test of oil fuel in a Hohenstein water-tube marine boiler, January 16, 1903.*

[Six hours' duration with 1-inch forced draft, using Best burner, air.]

Time.	Steam pressure by gauge.	Temperature of feed.	Calorimeter.			Gauge glass.	Temperature.					Revolutions of air compressor.
							Inside.					
			T₁.	T₂.	Q.		Dry.	Wet.	Air in fireroom.	Air for burner.	Gases at base of stack.	
	Lbs.	° *F.*	° *F.*	° *F.*		*Ins.*	° *F.*	° *F.*	° *F.*	° *F.*	° *F.*	
10 a. m....	275	111	406	292	0.9752	1.5	.....	.....	80	338	.....	70
10.15 a. m.	280	104	406	292	.9752	1.75	.....	.....	80	346	.....	70
10.30 a. m.	280	106	406	292	.9752	1.5	107½	85	80	348	685	71
10.45 a. m.	280	108	404	292	.9760	1.4	.....	.....	82	350	.....	72
11 a. m....	280	104	404	292	.9760	1.5	.....	.....	82	346	.....	71
11.15 a. m.	280	106	404	292	.9760	1	.....	.....	84	348	.....	70
11.30 a. m.	278	108	404	290	.9745	1.25	110	84½	88	348	680	70
11.45 a. m.	276	104	404	292	.9760	1.25	.....	.....	88	344	.....	70
12 m......	275	104	404	292	.9760	1.5	.....	.....	88	346	.....	70
12.15 p. m.	275	105	404	292	.9760	1.5	.....	.....	88	346	.....	70
12.30 p. m.	278	103	404	292	.9760	1	112	85	88	342	670	70
12.45 p. m.	280	104	400	292	.9775	1.5	.....	.....	88	340	.....	70
1 p. m	275	104	402	292	.9770	1.5	.....	.....	88	336	.....	70
1.15 p. m..	275	110	404	294	.9770	1	.....	.....	90	334	.....	70
1.30 p. m..	275	110	402	292	.9770	.75	114½	86½	90	336	665	70
1.45 p. m..	278	110	404	294	.9770	1	.....	.....	90	336	.....	70
2 p. m	275	111	400	294	.9785	1.5	.....	.....	90	334	.....	70
2.15 p. m..	275	110	402	292	.9770	1	.....	.....	90	330	.....	70
2.30 p. m..	278	111	402	292	.9770	1	117	88½	90	336	665	70
2.45 p. m..	278	108	402	292	.9770	1.5	.....	.....	91	336	.....	70
3 p. m	275	108	402	294	.9768	1.5	.....	.....	91	336	.....	70
3.15 p. m..	275	108	400	294	.9785	2	.....	.....	91	338	.....	70
3.30 p. m..	270	104	400	292	.9775	2	118	89½	90	336	700	70
3.45 p. m..	280	114	402	294	.9768	1.5	.....	.....	89	338	.....	70
4 p. m	278	104	404	294	.9770	1.5	.....	.....	90	334	.....	70
Average ..	277	107	403	292.6	.9765	.....	.....	.....	87.4	340	.....	70.2

Barometer at noon, 30.04 inches.

Lighted fires at 6 a. m.; 275 pounds pressure at 7 a. m.; 1 inch forced draft at 9 a. m.; test began at 10 a. m.

Weather clear.

Air openings into furnace during the trial 3 ▭ +4 ⊙, ducts open.

Hygrometer 3 feet front of mid furnace opening.

No. 35.—*Test of oil fuel in a Hohenstein water-tube marine boiler, January 16, 1903.*

[Six hours' duration with 1-inch forced draft, using Best burner, air.]

Time.	Air pressure on burner.	Pressure on oil system.	Draft pressures.				Flue gases.			Revolutions of fan.	Oil burned per hour.	Feed water per hour.
			Tube chamber.		Above tubes below drums.	Base of stack.	CO$_2$.	O.	CO.			
			Front.	Back.								
	Lbs.	*Lbs.*					*P. ct.*	*P. ct.*	*P. ct.*		*Lbs.*	*Lbs.*
10 a. m....	71	25	0.43	0.45	−0.03	−0.6	.....	.....	.....	285	......	......
10.15 a. m.	71	25	.43	.45	.02	−.55	.....	.....	.....	285	......	......
10.30 a. m.	71	25	.43	.45	−.02	−.55	8.2	10.0	0	285	......	......
10.45 a. m.	70	25	.43	.45	−.02	−.55	.....	.....	.....	284	......	......
11 a. m....	71	25	.43	.45	−.02	−.55	.....	.....	.....	285	1,772	19,030
11.15 a. m.	71	25	.43	.45	−.02	−.55	.....	.....	.....	285	......	......
11.30 a. m.	71	25	.43	.45	−.02	−.55	.....	.....	.....	285	......	......
11.45 a. m.	71	25	.43	.45	−.02	−.55	.....	.....	.....	285	......	......
12 m......	71	25	.43	.45	−.02	−.55	.....	.....	.....	285	1,730	18,588
12.15 p. m.	71	25	.43	.45	−.02	−.55	.....	.....	.....	285	......	......
12.30 p. m.	71	25	.43	.45	−.02	−.55	7.6	10.6	0.1	286	......	......
12.45 p. m.	71	25	.43	.45	−.02	−.55	.....	.....	.....	285	......	......
1 p. m	71	25	.43	.45	−.02	−.55	.....	.....	.....	285	1,670	17,804
1.15 p. m..	71	25	.43	.45	−.02	.55	.....	.....	.....	285	......	......
1.30 p. m..	71	25	.43	.45	−.02	.55	.....	.....	.....	285	......	......
1.45 p. m..	71	25	.43	.45	−.02	.55	.....	.....	.....	285	......	......
2 p. m	71	25	.43	.45	−.02	.55	.....	.....	.....	284	1,688	18,336
2.15 p. m..	71	25	.43	.45	−.02	−.55	.....	.....	.....	284	......	......
2.30 p. m..	71	25	.43	.45	−.02	−.55	7.4	11.2	0	283	......	......
2.45 p. m..	71	25	.43	.45	.02	−.55	.....	.....	.....	284	......	......
3 p. m	71	25	.43	.45	−.02	−.55	.....	.....	.....	285	1,697	18,452
3.15 p. m..	71	25	.43	.45	−.02	−.55	.....	.....	.....	285	......	......
3.30 p. m..	71	23	.43	.45	−.02	−.55	.....	.....	.....	284	......	......
3.45 p. m..	71	23	.43	.45	−.02	−.55	.....	.....	.....	285	......	......
4 p. m	71	25	.43	.45	−.02	−.55	.....	.....	.....	285	1,723	18,735
Average ..	71	25	.43	.45	−.02	−.55	.....	.....	.....	284.8	1,713	18,491

Temperature of oil in weigh tank, 36° F.
Draft pressure in fireroom, 1 inch.
Draft pressure at furnace, 0.8 inch.
Draft pressure in combustion chamber, 0.45 inch.
Total pounds oil burned, 10,280.
Total pounds feed water, 110,945.

No. 36.—*Test of oil fuel in a Hohenstein water-tube marine boiler, January 17, 1903.*

[Five hours' duration with 2-inch forced draft, using Best burner, under air.]

Time.	Steam pressure by gauge.	Temperature of feed.	Calorimeter.			Gauge glass.	Temperature.				Air pressure on burner.	Pressure on oil system.
			T$_1$.	T$_2$.	Q.		Inside.		Air in fireroom.	Air for burner.		
							Dry.	Wet.				
	Lbs.	° *F.*	° *F.*	° *F.*		*Ins.*	° *F.*	° *F.*	° *F.*	° *F.*	*Lbs.*	*Lbs.*
10 a. m...	275	102	404	292	0.9760	2.5	.....	.....	72	346	70	25
10.15 a. m.	274	111	404	290	.9745	1.5	.....	.....	74	338	70	25
10.30 a. m.	275	105	404	290	.9745	1.5	92	72	74	330	70	25
10.45 a. m.	274	109	402	290	.9755	1.5	.....	.....	74	330	70	25
11 a. m...	270	111	403	288	.9738	1.5	.....	.....	74	338	70	25
11.15 a. m.	275	90	400	288	.9750	1.5	.....	.....	75	350	70	25
11.30 a. m.	275	104	400	288	.9750	1.5	98	75	76	366	70	25
11.45 a. m.	275	102	400	288	.9750	1	.....	.....	78	368	70	25
12 m	278	108	400	290	.9760	1.5	.....	.....	78	370	70	25
12.15 p. m.	275	106	400	290	.9760	1.5	100	77	78	364	70	25
12.30 p. m.	270	104	400	290	.9760	1.25	.....	.....	80	364	70	23
12.45 p. m.	272	100	398	288	.9765	1	.....	.....	80	364	70	23
1 p. m....	275	99	402	290	.9755	1.5	.....	.....	82	362	70	23
1.15 p. m..	275	102	400	290	.9760	1.5	103	78	82	366	70	23
1.30 p. m..	275	103	400	290	.9760	1	.....	.....	82	366	70	23
1.45 p. m..	275	103	400	290	.9760	1.5	.....	.....	84	370	70	23
2 p. m....	275	92	400	290	.9760	1.5	.....	.....	84	370	70	23
2.15 p. m..	270	100	400	290	.9760	1.5	.....	.....	86	364	70	23
2.30 p. m..	270	100	404	292	.9760	1.5	108	81	86	360	70	23
2.45 p. m..	275	102	402	292	.9768	1.5	.....	.....	88	368	70	23
3 p. m....	275	100	402	292	.9768	1.5	.....	.....	88	366	70	23
Average ..	274	102	......	.....	.9757	.....	.....	.....	79.8	358	70	24

Barometer at noon, 30.70 inches.

Lighted fires at 6 a. m.; 275 pounds steam at 6.45 a. m.; 2 inches forced draft at 9 a. m.; test begins at 10 a. m.

Weather overcast.

Air openings into furnace: 10 a. m. till 11, 3□ + 4 ◓ (ducts open); 11 till end, 3□ + 4 ◓ (ducts open).

There was a deposit of carbon of about 6 square inches on back of furnace after this run.

2 feet front of mid furnace opening.

No. 36.—*Test of oil fuel in a Hohenstein water-tube marine boiler, January 17, 1903.*

[Five hours' duration with 2-inch forced draft, using Best burner, under air.]

Time.	Draft pressures.						Flue gases.			Revolutions of fan blower.	Oil burned per hour.	Feed water per hour.
	Furnace.	Combustion chamber.	Tube chamber. Front.	Tube chamber. Back.	Above tubes below drums.	Base of stack.	CO₂.	O.	CO.			
							P. ct.	*P. ct.*	*P. ct.*		*Lbs.*	*Lbs.*
10 a. m	1.45	0.95	0.93	0.95	0.3	0.5	......	......	......	373	......	......
10.15 a. m.	1.45	.95	.93	.95	.3	.5	......	......	......	372	......	......
10.30 a. m.	1.45	.95	.93	.95	.3	.5	5.8	12.5	0.2	372	......	......
10.45 a. m.	1.45	.95	.93	.95	.3	.5	......	......	......	372	......	......
11 a. m	1.45	.95	.93	.95	.3	.5	......	......	......	375	1,750	17,415
11.15 a. m.	1.45	.95	.93	.95	.3	.5	......	......	......	375	......	......
11.30 a. m.	1.45	.95	.93	.95	.3	.5	......	......	......	378	......	......
11.45 a. m.	1.45	.95	.93	.95	.3	.5	......	......	......	376	......	......
12 m	1.45	.95	.93	.95	.3	.5	......	......	......	375	2,059	21,126
12.15 p. m.	1.45	.95	.93	.95	.3	.5	......	......	......	376	......	......
12.30 p. m.	1.45	.95	.93	.95	.3	.5	6.6	11.4	.2	372	......	......
12.45 p. m.	1.45	.95	.93	.95	.3	.5	......	......	......	372	......	......
1 p. m	1.45	.95	.93	.95	.3	.5	......	......	......	375	1,978	20,752
1.15 p. m.	1.45	.95	.93	.95	.3	.5	......	......	......	375	......	......
1.30 p. m.	1.45	.95	.93	.95	.3	.5	7.0	10.9	0	375	......	......
1.45 p. m.	1.45	.95	.93	.95	.3	.5	......	......	......	375	......	......
2 p. m	1.45	.95	.93	.95	.3	.5	......	......	......	375	2,067	21,581
2.15 p. m.	1.45	.95	.93	.95	.3	.5	......	......	......	375	......	......
2.30 p. m.	1.45	.95	.93	.95	.3	.5	......	......	......	375	......	......
2.45 p. m.	1.45	.95	.93	.95	.3	.5	......	......	......	375	......	......
3 p. m	1.45	.95	.93	.95	.3	.5	......	......	......	375	1,970	20,654
Average	1.45	.95	.93	.95	.3	.5	......	......	......	375	1,965	20,306

Boiler was blown down one-half glass before this run.
Temperature of oil in weigh tank, 36° F.
Revolutions of air compressor, 74.
Draft pressure in fireroom, 2 inches.
Total pounds oil burned, 9,824.
Total pounds feed water, 101,528.

No. 37.—*Test of oil fuel in a Hohenstein water-tube marine boiler, January 19, 1903.*

[Three hours' duration with 3-inch forced draft, using Best burner, under air.]

Time.	Steam-pressure gauge.	Temperature of feed.	Calorimeter.			Gauge glass.	Temperature.					Revolutions of air compressor.
			T₁.	T₂.	Q.		Inside.		Air in fireroom.	Air for burner.	Gases at base of stack.	
							Dry.	Wet.				
	Lbs.	° *F.*	° *F.*	° *F.*		*Ins.*	° *F.*	° *F.*	° *F.*	° *F.*	° *F.*	
11.15 a. m.	275	100	400	286	0.9740	1.75	.....	.....	58	378	......	68
11.30 a. m.	273	100	402	286	.9733	1.5	.....	.....	58	370	......	68
11.45 a. m.	273	104	402	286	.9733	1.5	70	61½	56	368	710	68
12 m.	275	100	402	289	.9750	2.0	.....	.....	56	354	......	68
12.15 p. m.	273	86	400	288	.9740	1.5	.....	.....	58	370	......	68
12.30 p. m.	275	91	402	290	.9755	1.5	.....	.....	58	380	......	69
12.45 p. m.	275	93	402	290	.9755	1.0	72½	62	59	366	725	69
1 p. m.	275	100	402	290	.9755	1.5	.....	.....	60	360	......	69
1.15 p. m.	273	98	402	290	.9755	1.75	.....	.....	60	360	......	69
1.30 p. m.	278	100	402	290	.9755	1.5	.....	.....	60	364	......	69
1.45 p. m.	275	100	402	290	.9755	1.5	74	62	61	362	715	69
2 p. m.	275	98	402	290	.9755	1.5	.....	.....	61	362	......	69
2.15 p. m.	275	94	402	290	.9755	1:75	.....	.....	62	360	......	69
Average	275	97	.....	.....	.9749	.....	72	62	59	366	717	68.6

Barometer at noon, 30.55 inches.
Test begun at 11.15 a. m.
Four No. 2 burners in use.
Weather, cold and clear.
Air openings into furnace, 3 □ and 4 ⊙ (air ducts open).

No. 37.—*Test of oil fuel in a Hohenstein water-tube marine boiler, January 19, 1903.*

[Three hours' duration with 3-inch forced draft, using Best burner, under air.]

Time.	Draft pressures.						Flue gases.			Revolutions of fan blower.	Oil burned per hour.	Feed water per hour.
	Furnace.	Combustion chamber.	Tube chamber.		Above tubes, below drums.	Base of stack.	CO$_2$.	O.	CO.			
			Front.	Back.								
							P. ct.	*P. ct.*	*P. ct.*		*Lbs.*	*Lbs.*
11.15 a. m.	2.6	1.62	1.6	1.62	0.6	−0.6	.....	.....	.....	445	.....	.....
11.30 a. m.	2.6	1.62	1.6	1.62	.6	− .6	.....	.....	.....	445	.....	.....
11.45 a. m.	2.6	1.62	1.6	1.62	.6	− .6	6.7	12.3	0.1	445	.....	.....
12 m.	2.6	1.62	1.6	1.62	.6	− .6	.....	.....	.....	445	.....	.....
12.15 p. m.	2.6	1.62	1.6	1.62	.6	− .6	.....	.....	.....	445	2,294	22,322
12.30 p. m.	2.6	1.62	1.6	1.62	.6	− .6	.....	.....	.....	445	.....	.....
12.45 p. m.	2.6	1.62	1.6	1.62	.6	− .6	.....	.....	.....	445	.....	.....
1 p. m.	2.6	1.62	1.6	1.62	.6	− .6	.....	.....	.....	445	.....	.....
1.15 p. m.	2.6	1.62	1.6	1.62	.6	− .6	.....	.....	.....	445	2,354	22,796
1.30 p. m.	2.6	1.62	1.6	1.62	.6	− .6	.....	.....	.....	445	.....	.....
1.45 p. m.	2.6	1.62	1.6	1.62	.6	− .6	.....	.....	.....	445	.....	.....
2 p. m.	2.6	1.62	1.6	1.62	.6	− .6	.....	.....	.....	445	.....	.....
2.15 p. m.	2.6	1.62	1.6	1.62	.6	− .6	.....	.....	.....	445	2,302	22,502
Average	2.6	1.62	1.6	1.62	.6	− .6	6.7	12.3	0.1	445	2,317	22,540

Started fires at 6.30 a. m. Shut down at 7.15 on account of frozen suction pipe, having at the time 80 pounds of steam.

Temperature of oil in weigh tank, 28° F.

Air pressure on burner, 70 pounds.

Pressure on oil system, 20 pounds.

Draft pressure in fireroom, 3 inches.

Total pounds oil burned, 6,950.

Total pounds feed water, 67,620.

No. 38.—*Test of oil fuel in a Hohenstein water-tube marine boiler, January 20, 1903.*

[Six hours' duration with natural draft, using Best burner, under steam.]

Time.	Steam pressure, gauge.	Temperature of feed.	Calorimeter.			Gauge glass.	Temperature.				Steam for burner.	Pressure on burner.
							Inside.					
			T₁.	T₂.	Q.		Dry.	Wet.	Air in fireroom.	Oil in weigh tank.		
	Lbs.	° *F.*	° *F.*	° *F.*		*Ins.*	° *F.*	° *F.*	*F.*	° *F.*	° *F.*	*Lbs.*
11.30 a. m.	275	120	404	302	0.9815	1	.....	.....	77	28	366	90
11.45 a. m.	275	120	406	304	.9820	.75	.....	.....	62	28	370	90
12 m......	275	120	406	304	.9820	.75	102½	83	60	28	364	91
12.15 p. m.	275	118	405	304	.9825	1	.....	.....	60	28	363	90
12.30 p. m.	275	120	405	302	.9812	.75	.....	.....	60	28	363	89
12.45 p. m.	273	120	408	304	.9815	.75	.....	.....	61	28	363	89
1 p. m	270	120	404	304	.9828	1	107	86½	62	28	366	90
1.15 p. m..	273	119	406	304	.9820	1	.....	.....	61	28	366	91
1.30 p. m..	275	120	404	304	.9828	.75	.....	.....	67	28	364	90
1.45 p. m..	275	120	406	304	.9820	1	.....	.....	66	28	356	90
2 p. m	277	120	404	304	.9828	.75	104	83½	70	28	352	90
2.15 p. m..	270	120	408	304	.9815	1	.....	.....	62	28	350	90
2.30 p. m..	276	124	404	302	.9815	.75	.....	.....	64	30	350	91
2.45 p. m..	270	118	404	302	.9815	1	.....	.....	62	30	352	89
3 p. m	275	122	406	304	.9820	1	100	82	64	30	360	89
3.15 p. m..	275	120	406	302	.9810	1	.....	.....	60	30	360	90
3.30 p. m..	275	120	404	304	.9828	1	.....	.....	60	30	358	90
3.45 p. m..	275	120	406	302	.9810	1	.....	.....	62	30	350	90
4 p. m	270	120	408	304	.9815	1	98½	81½	65	30	346	92
4.15 p. m..	275	119	406	302	.9810	1	.....	.....	60	30	356	91
4.30 p. m..	275	120	408	302	.9800	.75	.....	.....	65	30	350	90
4.45 p. m..	275	120	406	304	.9820	1	.....	.....	66	30	356	91
5 p. m	275	120	404	304	.9828	1	105	86	66	30	358	91
5.15 p. m..	275	120	406	304	.9820	.75	.....	.....	66	30	360	90
5.30 p. m..	270	120	406	304	.9820	1	.....	.....	67	30	358	90
Average ..	274	120	......	......	.9818	.....	.....	.....	63	29	358	90.5

Barometer at noon, 30.29 inches.
Test starts at 11.30 a. m.
Boiler had been under 275 pounds steam since 7.30 a. m.
Weather overcast and damp.
Air into furnace, 3 □ + 4 ⊙ (ducts open).
This run is a duplication of that of the 31st ult., with the idea of reducing the amount of steam used for atomizing.

No. 38.—*Test of oil fuel in a Hohenstein water-tube marine boiler, January 20, 1903.*

[Six hours' duration with natural draft, using Best burner, under steam.]

Time.	Draft pressures.						Flue gases.			Oil burned per hour.	Feed water per hour.	Steam for burners (feed water Scotch boiler) per hour.
	Furnace.	Combustion chamber.	Tube chamber. Front.	Tube chamber. Back.	Above tubes, below drums.	Base of stack.	CO₂.	O.	CO.			
							P. ct.	*P. ct.*	*P. ct.*	*Lbs.*	*Lbs.*	*Lbs.*
11.30 a. m.	0.12	0.28	0.26	0.28	0.44	0.62						
11.45 a. m.	.12	.28	.26	.28	.44	.62						
12 m.	.12	.28	.26	.28	.44	.62	7	10.2	0.2			
12.15 p. m.	.12	.28	.26	.28	.44	.62						
12.30 p. m.	.12	.28	.26	.28	.44	.62				1,283	14,990	836
12.45 p. m.	.12	.28	.26	.28	.44	.61						
1 p. m.	.12	.28	.26	.28	.44	.62						
1.15 p. m.	.12	.28	.26	.28	.44	.62						
1.30 p. m.	.12	.28	.26	.28	.44	.62				1,279	14,991	610
1.45 p. m.	.12	.28	.26	.28	.44	.62						
2 p. m.	.12	.28	.26	.28	.44	.62	7.4	10.6	.4			
2.15 p. m.	.12	.28	.26	.28	.44	.62						
2.30 p. m.	.11	.27	.26	.28	.44	.61				1,205	14,372	625
2.45 p. m.	.11	.28	.26	.28	.44	.61						
3 p. m.	.11	.28	.26	.28	.44	.61						
3.15 p. m.	.11	.28	.26	.28	.44	.61						
3.30 p. m.	.12	.28	.26	.28	.44	.61				1,184	15,110	535
3.45 p. m.	.12	.28	.26	.28	.44	.61						
4 p. m.	.12	.28	.26	.28	.44	.61	6.9	11.4	.2			
4.15 p. m.	.12	.28	.26	.28	.44	.61						
4.30 p. m.	.12	.28	.26	.28	.44	.61				1,105	12,684	543
4.45 p. m.	.11	.28	.26	.28	.44	.61						
5 p. m.	.11	.28	.26	.28	.44	.61						
5.15 p. m.	.11	.28	.26	.28	.44	.61						
5.30 p. m.	.11	.28	.26	.28	.44	.61				1,160	13,924	595
Average	.117	.28	.26	.28	.44	.614				1,219	14,345	624

Boiler was blown down one-half glass before test.
Pressure on oil system (Scotch boiler), 20 pounds.
Total pounds oil burned, 7,216.
Total pounds feed water, 86,071.
Total pounds steam for burners, 3,744.

No. 39.—*Test of oil fuel in a Hohenstein water-tube marine boiler, February 6, 1903.*

[Seven hours' duration with natural draft, using Advance burner, under steam—60 pounds steam, 60 pounds oil.]

Time.	Steam pressure by gauge.	Temperature of feed.	Calorimeter.			Gauge glass.	Temperature.					
							Inside.					
			T₁.	T₂.	Q.		Dry.	Wet.	Air in fire room.	Oil in weigh tank.	Steam for burner.	Gases at base of stack.
	Lbs.	° *F.*	° *F.*	° *F.*		*Ins.*	° *F.*	° *F.*	° *F.*	° *F.*	° *F.*	° *F.*
10.30 a. m.	275	114	406	308	0.9845	2	.....	.....	76	36	376	......
10.45 a. m.	270	120	406	308	.9845	1	.....	.....	78	.....	388	......
11 a. m.	275	120	404	308	.9852	1.5	121	95	78	.....	370	605
11.15 a. m.	280	118	408	308	.9835	1.5	.....	.....	80	.....	380	......
11.30 a. m.	278	120	406	308	.9845	1.5	.....	.....	80	36	380	......
11.45 a. m.	275	120	406	310	.9855	1.5	.....	.....	80	.....	372	......
12 m.	275	120	408	308	.9835	2	115	90	80	.....	366	600
12.15 p. m.	270	120	406	308	.9845	2	.....	.....	80	.....	366	......
12.30 p. m.	275	120	406	310	.9855	2	.....	.....	80	38	366	......
12.45 p. m.	275	120	406	308	.9845	1.5	.....	.....	80	.....	368	......
1 p. m.	275	120	406	308	.9845	1	118	93	80	.....	372	600
1.15 p. m.	275	120	406	310	.9855	1.5	.....	.....	80	.....	372	......
1.30 p. m.	275	120	406	308	.9845	2	.....	.....	80	38	372	......
1.45 p. m.	275	120	404	306	.9840	1.5	.....	.....	82	.....	378	......
2 p. m.	270	120	406	308	.9845	1.5	136½	103	84	.....	386	615
2.15 p. m.	275	117	404	310	.9861	1.5	.....	.....	84	.....	388	......
2.30 p. m.	275	118	406	310	.9855	2	.....	.....	84	38	384	......
2.45 p. m.	275	122	406	310	.9855	1.5	.....	.....	86	.....	392	......
3 p. m.	275	120	404	308	.9852	1.5	140	103	86	.....	390	615
3.15 p. m.	275	120	404	310	.9861	1.75	.....	.....	86	.....	382	......
3.30 p. m.	275	120	406	310	.9855	2.25	.....	.....	86	38	390	......
3.45 p. m.	275	120	404	308	.9852	1.5	.....	.....	86	.....	390	......
4 p. m.	274	118	406	308	.9845	1.5	142	103	87	.....	400	615
4.15 p. m.	275	120	406	310	.9855	1.5	.....	.....	88	.....	400	......
4.30 p. m.	275	118	402	308	.9860	2	.....	.....	88	38	398	......
4.45 p. m.	275	120	406	308	.9845	1.5	.....	.....	90	.....	404	......
5 p. m.	275	120	406	310	.9855	2	138	100	90	.....	404	620
5.15 p. m.	275	118	407	310	.9850	1.5	.....	.....	90	.....	400	......
5.30 p. m.	275	120	406	310	.9855	2	.....	.....	88	38	396	......
Average	275	119	.....	.....	.9850	.....	130	98	83	37.5	384	610

Barometer at noon, 30.29 inches.
Tests start at 10.30 a. m.
Weather, clear.
Air openings into furnace, 3 ❐ and 6 ⊙ —. Deflectors used in the openings.
The burner functioned fairly, but still required constant attention.
Started fires at 6.45 a. m.; 275 pounds steam at 7.55 a. m.

No. 39.—*Test of oil fuel in a Hohenstein water-tube marine boiler, February 6, 1903.*

[Seven hours' duration with natural draft, using Advance burner, under steam—60 pounds steam, 60 pounds oil.]

Time.	Draft pressure.						Flue gases.			Oil burned per hour.	Feed water per hour.	Steam for burners (feed water, special boiler) per hour.
			Tube chamber.									
	Furnace.	Combustion chamber.	Front.	Back.	Above tubes, below drums.	Base of stack.	CO$_2$.	O.	CO.			
							P. ct.	*P. ct.*	*P. ct.*	*Lbs.*	*Lbs.*	*Lbs.*
10.30 a. m.	0.1	0.25	0.19	0.23	0.37	0.53						
10.45 a. m.	.1	.25	.2	.23	.38	.54						
11 a. m	.11	.23	.21	.23	.39	.54						
11.15 a. m.	.11	.24	.21	.23	.40	.54						
11.30 a. m.	.1	.24	.2	.23	.39	.54				940	9,942	515
11.45 a. m.	.11	.23	.2	.23	.39	.54						
12 m	.11	.23	.2	.23	.39	.54						
12.15 p. m.	.11	.22	.19	.22	.37	.53						
12.30 p. m.	.11	.22	.19	.22	.37	.53				877	9,790	589
12.45 p. m.	.1	.22	.19	.22	.37	.52						
1 p. m	.1	.22	.19	.22	.37	.52						
1.15 p. m.	.1	.23	.2	.23	.37	.53						
1.30 p. m.	.1	.22	.19	.22	.39	.52				824	9,881	566
1.45 p. m.	.1	.22	.19	.22	.39	.52						
2 p. m	.09	.21	.18	.21	.36	.50	7.4	10.6	0.1			
2.15 p. m.	.09	.21	.18	.21	.36	.50						
2.30 p. m.	.09	.21	.18	.21	.36	.50				1,036	11,050	548
2.45 p. m.	.09	.21	.18	.21	.37	.50						
3 p. m	.09	.22	.19	.22	.39	.53						
3.15 p. m.	.09	.22	.19	.22	.39	.53						
3.30 p. m.	.09	.22	.19	.22	.39	.53				1,017	10,562	662
3.45 p. m.	.09	.22	.19	.22	.39	.53						
4 p. m	.09	.22	.19	.22	.39	.53						
4.15 p. m.	.09	.22	.19	.22	.39	.53						
4.30 p. m.	.09	.22	.19	.22	.39	.53				1,067	11,583	488
4.45 p. m.	.09	.23	.19	.22	.39	.53						
5 p. m	.09	.22	.19	.22	.39	.53						
5.15 p. m.	.09	.22	.19	.22	.39	.53						
5.30 p. m.	.09	.22	.19	.22	.39	.53				1,068	11,884	568
Average	.097	.224	.192	.221	.382	.526	7.4	10.6	.1	975.5	10,670	562

Steam pressure on burner, 60 pounds.
Pressure on oil system, 60 pounds.
Total pounds oil burned, 6,829.
Total pounds feed water, 74,692.
Total pounds steam for burners, 3,936.

No. 40.—*Test of oil fuel in a Hohenstein water-tube marine boiler, February 9, 1903.*

[Eight hours' duration with natural draft, using Advance burner, under steam—30 pounds steam, 40 pounds oil.]

Time.	Steam pressure by gauge.	Temperature of feed.	Calorimeter.			Gauge glass.	Temperature.				
			T_1.	T_2.	Q.		Inside.		Air in fireroom.	Steam for burner.	Gases at base of stack.
							Dry.	Wet.			
	Lbs.	° *F.*	° *F.*	° *F.*		*Ins.*	° *F.*	° *F.*	° *F.*	° *F.*	° *F.*
10.30 a. m	273	120	404	310	0.9865	1.5			73	398	
10.45 a. m	275	120	404	310	.9865	2			76	386	
11 a. m	275	120	404	308	.9852	1	117	90	78	384	675
11.15 a. m	275	119	402	308	.9860	2			78	388	
11.30 a. m	275	121	404	308	.9852	2			80	388	
11.45 a. m	275	124	404	308	.9852	1.5			80	400	
12 m	275	120	404	308	.9852	1	125	95	80	400	670
12.15 p. m	275	120	406	310	.9855	2			84	400	
12.30 p. m	275	120	406	310	.9855	1.5			80	400	
12.45 p. m	275	120	406	310	.9855	1.5			82	400	
1 p. m	275	120	406	310	.9855	1.5	124	93	82	396	655
1.15 p. m	275	120	402	308	.9860	1.5			82	398	
1.30 p. m	273	120	402	308	.9860	2			82	398	
1.45 p. m	278	120	402	308	.9860	2			82	398	
2 p. m	275	118	402	308	.9860	2.5	118	92	86	396	655
2.15 p. m	275	118	402	308	.9860	2.5			86	406	
2.30 p. m	275	120	404	308	.9852	2.25			84	390	
2.45 p. m	278	124	402	308	.9860	1			86	402	
3 p. m	275	118	402	308	.9860	1.5	116	90	86	400	655
3.15 p. m	275	120	404	308	.9852	2			90	402	
3.30 p. m	275	120	402	306	.9860	2.25			88	402	
3.45 p. m	274	120	402	308	.9860	1.5			88	394	
4 p. m	275	120	402	308	.9860	1	132½	99½	86	386	675
4.15 p. m	275	120	402	308	.9860	1			88	394	
4.30 p. m	276	118	402	308	.9860	2			86	388	
4.45 p. m	275	124	404	310	.9865	1			90	390	
5 p. m	275	120	404	310	.9865	1	132½	103	88	390	660
5.15 p. m	275	120	404	308	.9852	1.5			84	396	
5.30 p. m	275	120	406	308	.9843	2			86	398	
5.45 p. m	275	120	402	308	.9860	1			89	398	
6 p. m	275	120	402	308	.9860	1	137	103	89	398	650
6.15 p. m	275	120	402	308	.9860	1.5			89	400	
6.30 p. m	278	120	402	308	.9860	2			84	400	
Average	275	120			.9858		125	95.6	84	396	662

Barometer at noon, 30.15 inches.
Tests started at 10.30 a. m.
Weather, clear and cold; fresh breeze from northwest.
Air openings into furnace, 3 and 6 ⊙. Deflectors used in openings.

NOTE.—With these conditions as given—of low pressure of burner steam, and greater pressure on oil than on the spraying steam, the burners functioned very satisfactorily, requiring very little attention, except an occasional increase in the oil admission for the purpose of clearing the oil holes in the burner. With the lower pressures the spray seems to take the rifling better and to tend to follow the bell muzzle.

No. 40.—*Test of oil fuel in a Hohenstein water-tube marine boiler, February 9, 1903.*

[Eight hours' duration with natural draft, using Advance burner, under steam—30 pounds steam, 40 pounds oil.]

Time.	Draft pressure.						Flue gases.			Oil burned per hour.	Feed water per hour.	Steam for burners (feed water, special boiler) per hour.
			Tube chamber.									
	Furnace.	Combustion chamber.	Front.	Back.	Above tubes, below drums.	Base of stack.	CO$_2$.	O.	CO.			
							P. ct.	*P. ct.*	*P. ct.*	*Lbs.*	*Lbs.*	*Lbs.*
10.30 a. m.	0.05	0.22	0.17	0.21	0.4	0.52						
10.45 a. m.	.05	.22	.17	.21	.4	.52						
11 a. m.	.05	.22	.16	.19	.4	.52	8.0	9.00				
11.15 a. m.	.05	.22	.16	.19	.4	.52						
11.30 a. m.	.05	.22	.16	.19	.37	.54				1,211	13,510	554
11.45 a. m.	.05	.20	.17	.20	.35	.51						
12 m.	.05	.20	.17	.20	.35	.51						
12.15 p. m.	.05	.20	.17	.20	.35	.51						
12.30 p. m.	.05	.20	.17	.20	.36	.55				1,204	13,498	621
12.45 p. m.	.05	.20	.17	.20	.36	.55						
1 p. m.	.05	.20	.17	.20	.36	.55	7.7	9.80				
1.15 p. m.	.05	.20	.17	.20	.36	.55						
1.30 p. m.	.05	.20	.17	.20	.36	.55				1,184	13,689	564
1.45 p. m.	.05	.21	.17	.20	.36	.55						
2 p. m.	.05	.20	.17	.20	.36	.55						
2.15 p. m.	.05	.20	.17	.20	.36	.55						
2.30 p. m.	.05	.20	.17	.20	.36	.55				1,204	13,562	494
2.45 p. m.	.05	.20	.17	.20	.38	.55						
3 p. m.	.05	.20	.17	.20	.38	.55	7.7	11.20				
3.15 p. m.	.05	.20	.17	.20	.38	.55						
3.30 p. m.	.05	.20	.18	.21	.36	.55				1,201	13,732	481
3.45 p. m.	.05	.20	.17	.21	.36	.55						
4 p. m.	.05	.20	.17	.21	.36	.55						
4.15 p. m.	.05	.20	.17	.21	.36	.55						
4.30 p. m.	.05	.20	.17	.20	.36	.55				1,180	13,360	500
4.45 p. m.	.05	.20	.17	.20	.36	.55						
5 p. m.	.05	.20	.17	.20	.36	.55	8.0	11.6	0.3			
5.15 p. m.	.05	.21	.18	.21	.4	.55						
5.30 p. m.	.05	.21	.18	.21	.4	.55				1,204	13,481	529
5.45 p. m.	.05	.21	.18	.21	.4	.55						
6 p. m.	.05	.21	.18	.21	.4	.55						
6.15 p. m.	.05	.21	.18	.21	.4	.55						
6.30 p. m.	.05	.21	.18	.21	.4	.55				1,190	13,653	464
Average	.05	.205	.170	.203	.373	.542	7.85	10.4	.075	1,197	13,566	526

Started fires at 7.15 a. m. (main boiler); 275 pounds steam at 8.10 a. m.
Temperature of oil in weigh tank, 37° F.
Steam pressure on burner, 30 pounds.
Pressure on oil system, 40 pounds.
Total pounds oil burned, 9,578.
Total pounds feed water, 108,485.
Total pounds steam for burners, 4,207.

No. 41.—*Test of oil fuel in a Hohenstein water-tube marine boiler, February 13, 1903.*

[Eight hours' duration with natural draft, using Advance burner (improved), under steam—20 pounds steam, 30-25 pounds oil.]

Time.	Steam pressure by gauge.	Temperature of feed.	Calorimeter.			Gauge glass.	Temperature.					Pressure on oil system.
			T₁.	T₂.	Q.		Inside.		Air in fireroom.	Steam for burner.	Gases at base of stack.	
							Dry.	Wet.				
	Lbs.	° *F.*	° *F.*	° *F.*		*Ins.*	° *F.*	° *F.*	° *F.*	° *F.*	° *F.*	
10.20 a. m.	275	120	400	306	0.9855	1.75	.....	.....	86	384	.....	30
10.35 a. m.	275	120	400	306	.9855	1.25	.....	.....	87	390	.....	30
10.50 a. m.	275	120	402	304	.9836	1	138	107	88	396	640	30
11.05 a. m.	275	117	400	306	.9855	1.5	.....	.....	92	406	.....	30
11.20 a. m.	275	118	404	306	.9840	1.75	.....	.....	95	404	.....	30
11.35 a. m.	275	120	402	306	.9850	1.5	.....	.....	98	400	.....	30
11.50 a. m.	275	124	400	306	.9855	1	145	107	102	400	630	30
12.05 p. m.	275	120	402	306	.9850	1.5	.....	.....	102	392	.....	30
12.20 p. m.	276	118	404	308	.9852	1.75	.....	.....	104	394	.....	30
12.35 p. m.	275	120	404	308	.9852	1	.....	.....	106	410	.....	30
12.50 p. m.	275	120	400	308	.9870	1	154	108	104	410	645	30
1.05 p. m.	275	120	402	308	.9860	1	.....	.....	106	402	.....	30
1.20 p. m.	275	120	402	308	.9860	2	.....	.....	106	404	.....	30
1.35 p. m.	275	120	402	308	.9860	1	.....	.....	108	402	.....	30
1.50 p. m.	275	119	400	308	.9870	1.5	154	107	106	410	670	30
2.05 p. m.	275	118	400	308	.9870	1.5	.....	.....	108	414	.....	30
2.20 p. m.	275	120	402	308	.9860	2	.....	.....	110	410	.....	30
2.35 p. m.	274	124	402	308	.9860	1.5	.....	.....	110	406	.....	25
2.50 p. m.	275	118	402	308	.9860	1.5	159	111	108	406	635	25
3.05 p. m.	275	116	402	308	.9860	1.75	.....	.....	106	406	.....	25
3.20 p. m.	275	120	402	306	.9850	1.75	.....	.....	106	408	.....	25
3.35 p. m.	275	120	400	306	.9855	1.5	.....	.....	108	406	.....	25
3.50 p. m.	275	120	400	306	.9855	1.75	160	111	110	406	650	25
4.05 p. m.	275	120	402	308	.9860	1.75	.....	.....	104	400	.....	25
4.20 p. m.	275	120	402	308	.9860	2	.....	.....	104	396	.....	25
4.35 p. m.	270	120	402	308	.9860	2	.....	.....	108	394	.....	25
4.50 p. m.	275	120	402	308	.9860	2	152	112	110	392	635	25
5.05 p. m.	275	120	400	308	.9870	1.5	.....	.....	110	392	.....	25
5.20 p. m.	275	120	400	308	.9870	2	.....	.....	110	392	.....	25
5.35 p. m.	270	120	400	308	.9870	2.25	.....	.....	108	398	.....	25
5.50 p. m.	275	124	400	308	.9870	1.5	160	115	106	404	650	25
6.05 p. m.	275	120	400	308	.9870	2	.....	.....	108	400	.....	25
6.20 p. m.	275	120	402	308	.9860	2	.....	.....	106	400	.....	25
Average	275	120	.....	.....	.9859	.....	153	110	104	401	644	27.6

Barometer at noon, 30.03 inches.
Test started at 10.20 a. m.
Weather, clear.
Air openings into furance 3 ⌜ and 6 ⊡.

Pressure on oil during first four hours was 30 pounds. Pressure on oil during second four hours was 25 pounds.

There were three deposits of carbon. Two of which were 1 foot in diameter, and the other 3 feet in diameter.

No. 41.—*Test of oil fuel in a Hohenstein water-tube marine boiler, February 13, 1903.*

[Eight hours' duration with natural draft, using Advance burner (improved), under steam—20 pounds steam, 30-25 pounds oil.]

Time.	Draft pressure.					Flue gases.			Smoke.	Oil burned per hour.	Feed water per hour.	Steam for burners (feed water, special boiler) per hour.
	Combustion chamber.	Tube chamber. Front.	Tube chamber. Back.	Above tubes, below drums.	Base of stack.	CO_2.	O.	CO.				
						P. ct.	*P. ct.*	*P. ct.*		*Lbs.*	*Lbs.*	*Lbs.*
10.20 a. m.	0.20	0.18	0.21	0.38	0.53					0	0	0
10.35 a. m.	.20	.18	.21	.38	.53							
10.50 a. m.	.20	.18	.21	.38	.53				½			
11.05 a. m.	.20	.18	.21	.39	.55							
11.20 a. m.	.20	.18	.21	.39	.55					1,161	12,839	409
11.35 a. m.	.20	.18	.21	.39	.55							
11.50 a. m.	.20	.18	.21	.39	.55				⅛			
12.05 p. m.	.20	.18	.21	.39	.55							
12.20 p. m.	.20	.18	.21	.39	.55					1,082	12,416	370
12.35 p. m.	.20	.18	.21	.37	.50							
12.50 p. m.	.20	.18	.21	.37	.50	7.6	9.8	0.2	¼			
1.05 p. m.	.20	.18	.21	.37	.50							
1.20 p. m.	.20	.18	.21	.37	.52					1,083	11,977	488
1.35 p. m.	.20	.18	.21	.38	.53							
1.50 p. m.	.20	.18	.21	.38	.53				¾			
2.05 p. m.	.20	.18	.21	.38	.53							
2.20 p. m.	.20	.18	.21	.38	.53					1,063	11,953	384
2.35 p. m.	.20	.18	.21	.38	.53							
2.50 p. m.	.20	.18	.21	.38	.53				¼			
3.05 p. m.	.20	.18	.21	.38	.53							
3.20 p. m.	.20	.18	.21	.38	.53					1,103	12,439	353
3.35 p. m.	.20	.18	.21	.38	.53							
3.50 p. m.	.20	.18	.21	.38	.53				⅛			
4.05 p. m.	.20	.18	.21	.38	.53							
4.20 p. m.	.20	.18	.20	.38	.53					1,106	12,666	361
4.35 p. m.	.18	.16	.20	.38	.51							
4.50 p. m.	.18	.16	.20	.38	.52	7	12.4	.2	⅛			
5.05 p. m.	.18	.16	.20	.38	.53							
5.20 p. m.	.19	.18	.20	.38	.53					1,055	12,018	385
5.35 p. m.	.19	.17	.20	.38	.53							
5.50 p. m.	.19	.17	.20	.38	.53				¼			
6.05 p. m.	.19	.17	.20	.38	.53							
6.20 p. m.	.19	.17	.20	.38	.53					1,088	12,127	348
Average	.197	.177	.21	.38	.53	7.3	11.1	.2	.3	1,093	12,304	387

Lighted fires at 7.05 a. m.; 275 pounds steam at 7.55 a. m.
Steam pressure on burner, 20 pounds.
Draft pressure in furnace, 0.05 inch.
Total pounds oil burned, 8,741.
Total pounds feed water, 98,435.
Total pounds steam for burners, 3,098.

No. 42.—*Test of oil fuel in a Hohenstein water-tube marine boiler, February 27, 1903.*

[Eight hours' duration with 2-inch forced draft, using Advance oil burner, under steam—20 pounds steam, 25 pounds oil.]

Time.	Steam pressure by gauge.	Temperature of feed.	Calorimeter.			Gauge glass.	Temperature.			Steam pressure on burners.	Pressure on oil system.
			T₁.	T₂.	Q.		Air in fireroom.	Steam for burner.	Gases at base of stack.		
	Lbs.	° *F.*	° *F.*	° *F.*		*Ins.*	° *F.*	° *F.*	° *F.*	*Lbs.*	*Lbs.*
1 p. m.....	275	118	402	280	0.9700	2	90	404	......	20	25
1.15 p. m..	275	120	400	290	.9762	2.25	90	406	......	20	25
1.30 p. m..	275	120	400	288	.9750	2	90	394	750	20	25
1.45 p. m..	273	120	402	288	.9745	2	90	386	......	20	25
2 p. m.....	275	118	400	288	.9750	1.5	90	398	......	20	25
2.15 p. m..	275	120	400	290	.9762	2	90	398	......	20	25
2.30 p. m..	275	120	400	290	.9762	1.5	90	394	705	20	25
2.45 p. m..	275	120	402	288	.9745	1.5	90	388	......	20	25
3 p. m.....	275	120	400	286	.9740	2	90	378	......	20	25
3.15 p. m..	273	118	400	288	.9750	1.5	90	384	......	20	25
3.30 p. m..	270	117	398	288	.9760	1.5	90	406	710	20	25
3.45 p. m..	275	120	398	290	.9765	1.5	90	410	......	20	25
4 p. m.....	275	120	398	290	.9765	2	90	410	......	20	25
4.15 p. m..	275	120	398	290	.9765	2	90	422	......	20	25
4.30 p. m..	275	118	398	290	.9765	1.5	90	424	700	20	25
4.45 p. m..	275	116	396	290	.9777	2	90	406	......	20	25
5 p. m.....	275	112	396	292	.9790	2	90	394	......	20	25
Average...	274	119	......	......	.9756	.....	90	400	714	20	25

Temperature of oil does not appear in log.
Barometer at noon, 30.26.
Weather: Overcast, with rain from 2.30 until close.
Air openings into furnace 3 ▢ and 6—⊙.
Steam valve, wide open.

No. 42.—*Test of oil fuel in a Hohenstein water-tube marine boiler, February 27, 1903.*

[Eight hours' duration with 2-inch forced draft, using Advance oil burner, under steam—20 pounds steam, 25 pounds oil.]

Time.	Draft pressure.							Smoke.	Fan.	Oil burned per hour.	Feed water per hour.	Steam for burners (feed water, special boiler) per hour.
	Fireroom.	Furnace.	Combustion chamber.	Tube chamber.		Above tubes, below drums.	Base of stack.					
				Front.	Back.							
										Lbs.	*Lbs.*	*Lbs.*
1 p. m....	2	1.7	1.2	1.2	1.3	0.45	—0.35	....	384	....	....	......
1.15 p. m...	2	1.7	1.2	1.2	1.2	.45	— .3	....	385	....	....	......
1.30 p. m..	2	1.7	1.2	1.2	1.2	.45	— .3	¾	385	....	....	......
1.45 p. m..	2	1.7	1.2	1.2	1.2	.42	— .28	....	385	....	....	......
2 p. m....	2	1.7	1.2	1.2	1.15	.35	— .32	....	385	1,591	14,918	410
2.15 p. m..	2	1.7	1.2	1.2	1.15	.35	— .32	....	384	....	....	......
2.30 p. m..	2	1.7	1.2	1.2	1.15	.35	— .32	¼	384	....	....	......
2.45 p. m..	2	1.7	1.2	1.2	1.15	.35	— .32	....	384	....	....	......
3 p. m....	2	1.7	1.2	1.2	1.15	.35	— .32	....	385	1,502	13,895	390
3.15 p. m..	2	1.7	1.2	1.2	1.15	.35	— .32	....	385	....	....	......
3.30 p. m..	2	1.7	1.2	1.2	1.15	.35	— .32	½	386	....	....	......
3.45 p. m..	2	1.7	1.2	1.2	1.15	.35	— .32	....	385	....	....	......
4 p. m....	2	1.7	1.2	1.2	1.15	.35	— .32	....	385	1,697	15,276	420
4.15 p. m..	2	1.7	1.2	1.2	1.15	.35	— .32	....	385	....	....	......
4.30 p. m..	2	1.7	1.2	1.2	1.15	.35	— .32	¼	385	....	....	......
4.45 p. m..	2	1.7	1.2	1.2	1.15	.35	— .32	....	385	....	....	......
5 p. m....	2	1.7	1.2	1.2	1.15	.35	— .32	....	384	1,788	17,285	460
Average ..	2	1.7	1.2	1.2	1.14	.372	— .32	.44	385	1,644.5	15,343	420

Gas analysis apparatus disabled.
Total pounds oil burned, 6,578.
Total pounds feed water, 61,374.
Total pounds steam for burners, 1,680.

No. 43.—*Test of oil fuel in a Hohenstein water-tube marine boiler, March 2, 1903.*

[Six hours' duration with 1-inch forced draft, using Advance oil burner, under steam—25 pounds oil, 20 pounds steam.]

Time.	Steam pressure by gauge.	Temperature of feed.	Calorimeter.			Gauge glass.	Temperature.					Steam pressure on burner.
							Inside.		Air in fireroom.	Steam for burner.	Gases at base of stack.	
			T₁.	T₂.	Q.		Dry.	Wet.				
	Lbs.	*°F.*	*°F.*	*°F.*		*Ins.*	*°F.*	*°F.*	*°F.*	*°F.*	*°F.*	*Lbs.*
11 a. m....	275	126	400	292	0.9775	2.25			80	356		20
11.15 a. m.	275	118	400	292	.9775	1.5			81	356		20
11.30 a. m.	275	125	400	292	.9775	1			81	364	700	20
11.45 a. m.	276	116	400	292	.9775	2			81	370		20
12 m......	272	114	400	292	.9775	2.25			83	380		20
12.15 p. m.	275	120	402	292	.9766	2.25			83	376		20
12.30 p. m.	260	120	402	292	.9766	1.5			82	364	710	20
12.45 p. m.	273	120	400	292	.9775	1.5			83	370		20
1 p. m	275	120	400	292	.9775	2			83	374		20
1.15 p. m..	275	120	400	292	.9775	2			83	380		20
1.30 p. m..	273	118	400	292	.9775	2.25	125	96	83	394	710	20
1.45 p. m..	275	120	400	292	.9775	1.5			84	380		20
2 p. m	275	116	400	292	.9775	2			86	384		20
2.15 p. m..	273	120	400	292	.9775	2.25			87	386		20
2.30 p. m..	272	120	400	292	.9775	2	118	93	88	388	700	20
2.45 p. m..	275	120	400	292	.9775	3			88	380		20
3 p. m	275	120	398	292	.9780	2.25			88	376		20
3.15 p. m..	275	120	400	292	.9775	2.25			87	380		20
3.30 p. m..	272	122	402	292	.9766	1.5	120	95	87	380	690	20
3.45 p. m..	275	120	400	292	.9775	2			88	388		20
4 p. m	278	118	400	294	.9785	2.25			88	384		20
4.15 p. m..	275	118	400	292	.9775	1.5			88	380		20
4.30 p. m..	275	118	400	292	.9775	2	118	95	88	380	680	20
4.45 p. m..	275	120	400	292	.9775	1.5			88	378		20
5 p. m	275	122	400	292	.9775	2.25			88	368		20
Average ..	274	120			.9775		120	95	85	376	698	20

Barometer at noon, 30.47 inches.

Test starts at 11 a. m.; lighted fires, 6.45 a. m.; 275 pounds of steam at 7.50 a. m.; shut down for repairs, 8.15 a. m.; restarted, 9 a. m.; forced draft at 10 a. m.; 1-inch forced draft at 10.30 a. m.

Weather, clear and cold.

Air openings into furnace 3 □ and 6 ⊙—11 a. m. until 2 p. m.; air openings into furnace 3 □ and 2 ⊙ and 4 ⊙.

Steam valve, wide open.

No. 43.—*Test of oil fuel in a Hohenstein water-tube marine boiler, March 2, 1903.*

[Six hours' duration with 1-inch forced draft, using Advance oil burner, under steam—25 pounds oil, 20 pounds steam.]

Time.	Draft pressure.					Flue gases.			Revolutions of fan.	Oil burned per hour.	Feed water per hour.	Steam for burners (feed water, special boiler) per hour.
	Combustion chamber.	Tube chamber.		Above tubes, below drums.	Base of stack.	CO$_2$.	O.	CO.				
		Front.	Back.									
						P.ct.	*P.ct.*	*P.ct.*		*Lbs.*	*Lbs.*	*Lbs.*
11 a. m....	0.44	0.42	0.44	−0.08	−0.5	....	....	....	280	....	....	.....
11.15 a. m.	.44	.42	.44	− .08	− .5	....	....	....	279	....	....	.....
11.30 a. m.	.44	.42	.45	− .08	− .5	....	....	....	278	....	....	.....
11.45 a. m.	.45	.42	.44	− .08	− .5	....	....	....	278	....	....	.....
12 m......	.45	.42	.44	.08	.5	....	....	....	278	1,334	12,827	455
12.15 p. m.	.45	.42	.45	− .08	− .5	....	....	....	278	....	....	.....
12.30 p. m.	.45	.42	.45	.08	− .5	....	....	....	278	....	....	.....
12.45 p. m.	.45	.42	.45	.1	− .5	....	....	....	278	....	....	.....
1 p. m	.45	.42	.45	− .1	− .5	....	....	....	280	1,310	12,889	426
1.15 p. m..	.45	.42	.45	− .1	− .5	....	....	....	280	....	....	.....
1.30 p. m..	.45	.42	.45	− .1	− .5	4.8	13.2	0.6	280	....	....	.....
1.45 p. m..	.45	.42	.45	− .1	− .5	....	....	....	279	....	....	.....
2 p. m	.45	.42	.45	− .1	− .5	....	....	....	280	1,524	14,911	614
2.15 p. m..	.45	.42	.45	− .1	− .5	....	....	....	280	....	....	.....
2.30 p. m..	.45	.42	.45	− .1	− .5	....	....	....	281	....	....	.....
2.45 p. m..	.45	.42	.45	− .1	− .5	....	....	....	281	....	....	.....
3 p. m	.45	.42	.45	− .1	− .5	....	....	....	281	1,444	14,639	394
3.15 p. m..	.45	.42	.45	.1	− .5	....	....	....	280	....	....	.....
3.30 p. m..	.45	.42	.45	− .1	− .5	....	....	....	284	....	....	.....
3.45 p. m..	.45	.42	.45	− .1	− .5	....	....	....	280	....	....	.....
4 p. m	.45	.42	.45	− .1	− .5	....	....	....	279	1,403	13,767	381
4.15 p. m..	.45	.42	.45	− .1	− .5	....	....	....	281	....	....	.....
4.30 p. m..	.45	.42	.45	.1	− .5	....	....	....	281	....	....	.....
4.45 p. m..	.45	.42	.45	− .1	− .5	....	....	....	281	....	....	.....
5 p. m	.45	.42	.45	− .1	− .5	....	....	....	280	1,370	13,453	413
Average ..	.45	.42	.45	− .094	− .5	4.8	13.2	0.6	280	1,397.5	13,747	447

Pressure on oil system, 25 pounds.
Draft pressure in fireroom, 1 inch.
Draft pressure in furnace, 0.8 inch.
Total pounds oil burned, 8,385.
Total pounds feed water, 82,486.
Total pounds steam for boiler, 2,683.

No. 44.—*Test of oil fuel in a Hohenstein water-tube marine boiler, March 3, 1903.*

[Three hours' duration with 3-inch forced draft, using Advance burner, under steam—steam, 20 pounds; oil, 25 pounds.]

Time.	Steam pressure by gauge.	Temperature of feed.	Calorimeter.			Gauge glass.	Temperature.					Steam pressure on burner.
			T₁.	T₂.	Q.		Inside. Wet.	Inside. Dry.	Air in fireroom.	Steam for burner.	Gases at base of stack.	
	Lbs.	° *F.*	° *F.*	° *F.*		*Ins.*	° *F.*	° *F.*	° *F.*	° *F.*	° *F.*	*Lbs.*
1.15 p. m..	275	120	398	288	0.9760	1.5	......	......	87	400	.....	20
1.30 p. m..	275	120	400	286	.9740	1.5	......	......	88	426	.....	20
1.45 p. m..	275	120	396	288	.9765	1.5	57	77	89	420	810	20
2 p. m	275	116	398	288	.9760	1.5	......	......	88	428	.....	20
2.15 p. m..	275	114	398	290	.9770	1.5	......	......	90	428	.....	20
2.30 p. m..	275	120	400	290	.9762	1.5	......	......	89	424	.....	20
2.45 p. m..	274	120	398	288	.9760	2	56	77	90	416	760	20
3 p. m	275	124	398	290	.9770	1.5	......	......	90	410	.....	20
3.15 p. m..	270	120	400	288	.9750	3	......	......	89	402	.....	20
3.30 p. m..	275	116	398	290	.9770	2	......	......	90	438	.....	20
3.45 p. m..	275	120	398	288	.9760	1.5	57	78	90	438	755	20
4 p. m	275	120	398	290	.9770	1	......	......	90	432	.....	20
4.15 p. m..	275	120	398	288	.9760	1	......	......	90	434	.....	20
Average ..	275	119	.....	.....	.9761	.....	56.6	77.3	89	423	775	20

Temperature of oil does not appear in the log.
Barometer at noon, 30.55 inches.
Test started at 1.15 p. m.; lighted fires 9 a. m.; 275 pounds steam at 9.40 a. m.; 3-inch forced draft at 12.15 p. m.
Weather: Clear.
Air openings to furnace 3 □ and 6 ⊙ steam valves wide open.

No. 44.—*Test of oil fuel in a Hohenstein water-tube marine boiler, March 3, 1903.*

[Three hours' duration with 3-inch forced draft, using Advance burner, under steam—steam, 20 pounds; oil, 25 pounds.]

Time.	Draft pressure.					Flue gases.			Revolutions of fan.	Oil burned per hour.	Feed water per hour.	Steam for burners (feed water, special burners) per hour.
	Combustion chamber.	Tube chamber.		Above tubes, below drums.	Base of stack.	CO₂.	O.	CO.				
		Front.	Back.									
						P. ct.	*P. ct.*	*P. ct.*		*Lbs.*	*Lbs.*	*Lbs.*
1.15 p. m.	1.9	1.9	1.7	0.68	—0.4				458			
1.30 p. m.	1.9	1.9	1.7	.68	— .4				458			
1.45 p. m.	1.82	1.82	1.64	.6	— .4				459			
2 p. m	1.82	1.82	1.64	.6	— .42				458			
2.15 p. m.	1.82	1.82	1.64	.6	— .42				458	2,075	18,872	459
2.30 p. m.	1.82	1.82	1.64	.6	— .42				458			
2.45 p. m.	1.82	1.82	1.64	.6	— .42	7	11	0.4	460			
3 p. m	1.82	1.82	1.64	.6	— .42				458			
3.15 p. m.	1.9	1.82	1.64	.6	— .42				458	1,855	16,971	428
3.30 p. m.	1.9	1.82	1.64	.6	— .42				458			
3.45 p. m.	1.9	1.82	1.64	.6	— .42				459			
4 p. m	1.86	1.86	1.63	.6	— .42				458			
4.15 p. m.	1.86	1.86	1.63	.6	— .42				458	2,075	18,846	412
Average	1.86	1.85	1.65	.61	— .42	7	11	.4	458	2,002	18,229	433

Pressure on oil system, 25 pounds.
Draft pressure in fireroom, 3 inches.
Draft pressure in furnace, 2.6 inches.
Total pounds oil burned, 6,005.
Total pounds feed water, 54,689.
Total pounds steam for burners, 1,299.

No. 45.—*Test of oil fuel in a Hohenstein water-tube marine boiler, March 14, 1903.*

[Four hours' duration with 3-inch forced draft, for maximum capacity, using Oil City Boiler Works burner, under steam.]

Time.	Steam pressure by gauge.	Temperature of feed.	Calorimeter.			Gauge glass.	Temperature.					Pressure on oil system.
							Inside.					
			T_1.	T_2.	Q.		Dry.	Wet.	Air in fireroom.	Steam or air for burner.	Gases at base of stack.	
	Lbs.	° *F.*	° *F.*	° *F.*		*Ins.*	° *F.*	° *F.*	° *F.*	° *F.*	° *F.*	*Lbs.*
1 p. m	275	110	400	282	0.9716	2	.....	.....	102	434	.....	35
1.15 p. m..	275	108	400	290	.9762	2	.....	.....	102	444	.....	40
1.30 p. m..	275	110	402	292	.9765	2	.....	.....	102	448	.....	40
1.45 p. m..	275	107	398	288	.9760	3	92	70	102	460	750	40
2 p. m	275	110	394	288	.9772	1.5	.....	.....	102	482	.....	40
2.15 p. m..	270	108	396	288	.9765	1	.....	.....	104	476	.....	40
2.30 p. m..	275	106	396	292	.9788	1	.....	.....	104	448	.....	30
2.45 p. m..	275	110	396	288	.9765	3	94½	71	104	448	850	35
3 p. m	275	114	398	288	.9760	2	.....	.....	104	448	.....	35
3.15 p. m..	276	110	396	288	.9765	2	.....	.....	105	440	.....	40
3.30 p. m..	275	106	400	290	.9762	1.5	.....	.....	104	436	.....	40
3.45 p. m..	275	110	398	288	.9760	4	95	71	104	438	820	42
4 p. m	275	108	400	286	.9740	4	.....	.....	104	442	.....	45
4.15 p. m..	278	108	400	292	.9775	2	.....	.....	104	442	.....	65
4.30 p. m..	275	104	400	290	.9762	2.5	.....	.....	104	444	.....	70
4.45 p. m..	275	106	400	292	.9775	2	.....	.....	104	440	855	70
5 p. m	275	104	400	290	.9762	2	.....	.....	104	430	.....	70
Average ..	275	108	.....	.....	.9762	.....	93.5	70.7	103.5	447	819	60

Barometer at noon, 30.2 inches.
Test for maximum capacity.
Throughout the greater part of the test the feed pump was run at maximum capacity, the height of water in the boiler being regulated by the adjustment of the burner.
Test starts at 1 p. m., lighted fires at 9 a. m.; 275 pounds of steam at 10 a. m.; 3-inch forced draft at 12 m.

No. 45.—*Test of oil fuel in a Hohenstein water-tube marine boiler, March 14, 1903.*

[Four hours' duration with 3-inch forced draft, for maximum capacity, using Oil City Boiler Works burner, under steam.]

Time.	Draft pressure.							Smoke.	Revolutions of fan.	Oil burned per hour.	Feed water per hour.	Steam for burners (feed water, special boiler) per hour.
	Fireroom.	Furnace.	Cumbustion chamber.	Tube chamber.		Above tubes, below drums.	Base of stack.					
				Front.	Back.							
										Lbs.	*Lbs.*	*Lbs.*
1 p. m	3	2.5	0.55	1.4	1.3	1.5	—0.3	.....	460	......	......	......
1.15 p. m..	3.9	3.2	.8	2	2	2	— .4	.....	510	......	......	......
1.30 p. m..	3.7	3	.9	1.9	2	2	— .4	.....	494	......	......	......
1.45 p. m..	3.7	3	.9	1.9	2	2	— .4	3	495	......	......	......
2 p. m	3.8	3.1	.8	2	2	2.1	— .45	.....	505	2,715	26,971	852
2.15 p. m..	3.7	3	.75	1.8	1.7	1.9	— .3	.....	508	......	......	......
2.30 p. m..	3.3	2.6	.55	1.6	1.5	1.7	— .5	.....	480	......	......	......
2.45 p. m..	3.3	2.6	.55	1.6	1.5	1.7	— .5	3½	478	......	......	......
3 p. m	4	3	1	1.9	2	2	— .6	.....	516	2,585	27,240	755
3.15 p. m..	3.3	2.6	.55	1.8	1.6	1.7	— .5	.....	478	......	......	......
3.30 p. m..	3.4	2.6	.55	1.8	1.6	1.7	— .5	.....	480	......	......	......
3.45 p. m..	3.9	3	1	2	1.9	2	— .4	1½	516	......	......	......
4 p. m	3.9	3.1	1	2	1.9	2	— .4	.....	518	2,310	25,435	852
4.15 p. m..	4	3.1	1	2	2	2	— .6	.....	520	......	......	......
4.30 p. m..	4	3.1	1	2	2	2	— .6	.....	522	......	......	......
4.45 p. m..	4	3.1	1.10	2	2	2	— .5	3	520	......	......	......
5 p. m	4	3.1	1.10	2	2	2	— .5	.....	522	2,850	28,611	780
Average ..	3.7	2.92	.83	1.87	1.82	1.90	— .46	2.75	501	2,615	27,064	810

Weather, clear and pleasant.
Air openings into furnace, 3 □ and 6 ⊙.
Steam pressure on burner, 20 pounds.
Total pounds oil burned, 10,460.
Total pounds feed water, 108,257.
Total pounds steam for burners, 3,239.

No. 46.—*Test of oil fuel in a Hohenstein water-tube marine boiler, April 9, 1903.*

[Eight hours' duration with natural draft, Texas oil, using Booth burner (Santa Fe Railway), under steam.]

Time.	Steam pressure by gauge.	Temperature of feed.	Calorimeter.			Gauge glass.	Temperature.					Steam pressure on burner (Scotch boiler).
			T₁.	T₂.	Q.		Inside.		Air in fireroom.	Steam for burner.	Gases at base of stack.	
							Dry.	Wet.				
	Lbs.	° *F.*	° *F.*	° *F.*		*Ins.*	° *F.*	° *F.*	° *F.*	° *F.*	° *F.*	*Lbs.*
9.15 a. m..	270	124	398	298	0.9816	1.75	.....	.....	78	330	......	90
9.30 a. m..	270	116	400	298	.9810	1	.....	.....	78	330	......	90
9.45 a. m..	273	120	400	298	.9810	1	72	60	81	334	......	90
10 a. m....	270	118	398	298	.9816	1	.....	.....	82	334	......	90
10.15 a. m.	270	116	400	298	.9810	1.75	.....	.....	84	334	......	90
10.30 a. m.	272	120	398	298	.9816	1.75	.....	.....	86	334	......	90
10.45 a. m.	274	120	398	298	.9816	1.75	73½	60	88	336	......	90
11 a. m....	275	121	398	298	.9816	1.5	.....	.....	88	336	......	91
11.15 a. m.	275	118	398	298	.9816	1.75	.....	.....	88	334	......	90
11.30 a. m.	273	118	398	298	.9816	1.75	.....	.....	87	330	......	90
11.45 a. m.	275	120	396	296	.9813	2	74	61	88	332	......	90
12 m......	275	120	394	296	.9820	1.75	.....	.....	86	334	......	90
12.15 p. m.	270	116	396	296	.9813	1.75	.....	.....	89	330	......	90
12.30 p. m.	274	120	396	296	.9813	2	.....	.....	88	332	......	90
12.45 p. m.	275	120	396	296	.9813	2	75	62	88	328	......	90
1 p. m.....	275	120	396	296	.9813	2	.....	.....	88	330	......	90
1.15 p. m..	270	120	400	298	.9810	2	.....	.....	90	330	......	90
1.30 p. m..	270	120	400	298	.9810	1.75	.....	.....	88	334	......	90
1.45 p. m..	270	116	394	296	.9820	1.75	78	64	90	330	450	90
2 p. m.....	270	120	396	296	.9813	2	.....	.....	90	334	......	90
2.15 p. m..	270	120	396	296	.9813	2.5	.....	.....	90	334	......	90
2.30 p. m..	265	124	398	296	.9805	1.75	.....	.....	90	336	......	90
2.45 p. m..	270	120	398	296	.9805	1.5	79	68	90	336	420	90
3 p. m.....	270	120	398	308	.9872	1.5	.....	.....	90	336	......	90
3.15 p. m..	270	120	398	308	.9872	1.75	.....	.....	90	336	......	90
3.30 p. m..	270	120	398	308	.9872	1.75	.....	.....	92	336	......	90
3.45 p. m..	270	118	396	306	.9870	2	82	65	92	336	560	90
4 p. m.....	270	120	398	308	.9872	1.75	.....	.....	90	336	......	90
4.15 p. m..	270	120	400	308	.9870	2	.....	.....	90	334	......	90
4.30 p. m..	270	118	400	308	.9870	1.75	.....	.....	88	336	......	90
4.45 p. m..	270	116	400	308	.9870	1.5	88	68½	88	336	420	90
5 p. m.....	268	116	396	308	.9880	1.75	.....	.....	90	336	......	90
5.15 p. m..	272	112	398	308	.9872	1.75	.....	.....	88	336	......	90
Average...	271	119	.....	.....	.9831	.....	78	64	88	334	462	90

Barometer at noon, 29.94 inches.

Started fires at 5.55 a. m.; 275 pounds steam at 6.40 a. m.; test starts at 9.15 a. m.

Weather, clear and warm.

Air into furnace: 9.15 to 11.15, 3 □ and 2 ⊙; 11.15 to 1.15, 3 □; 1.15 to end, 3 □ and 2 ⊙.

Only the center of the flat steam jet mixes with the oil, hence the burner appears to be extravagant of steam.

No. 46.—*Test of oil fuel in a Hohenstein water-tube marine boiler, April 9, 1903.*

[Eight hours' duration with natural draft, Texas oil, using Booth burner (Santa Fe Railway), under steam.]

Time.	Draft pressure.						Flue gases.		Smoke.	Oil burned per hour.	Feed water per hour.	Steam for burners (feed water, special boiler), per hour.
	Furnace.	Combustion chamber.	Tube chamber.		Above tubes, below drums.	Base of stack.	CO₂.	O.				
			Front.	Back.								
							P. ct.	*P. ct.*		*Lbs.*	*Lbs.*	*Lbs.*
9.15 a. m.	0.21	0.29	0.26	0.28	0.36	0.46						
9.30 a. m.	.21	.29	.26	.28	.36	.47						
9.45 a. m.	.21	.29	.26	.28	.36	.46			1½			
10 a. m.	.21	.29	.26	.28	.36	.47						
10.15 a. m.	.21	.29	.26	.28	.36	.46				747	8,415	835
10.30 a. m.	.21	.29	.26	.28	.36	.46						
10.45 a. m.	.21	.29	.26	.28	.35	.45			1½			
11 a. m.	.21	.29	.26	.28	.36	.45						
11.15 a. m.	.21	.29	.26	.28	.36	.45				750	8,828	945
11.30 a. m.	.21	.29	.26	.28	.36	.45						
11.45 a. m.	.21	.29	.26	.28	.36	.46	7	11.8	1			
12 m.	.21	.29	.26	.28	.36	.46						
12.15 p. m.	.21	.29	.26	.28	.36	.46				731	8,439	898
12.30 p. m.	.21	.29	.26	.28	.36	.46						
12.45 p. m.	.21	.29	.26	.28	.36	.46			2			
1 p. m.	.21	.29	.26	.28	.36	.46						
1.15 p. m.	.21	.29	.26	.28	.36	.46				680	8,031	1,039
1.30 p. m.	.20	.27	.27	.26	.34	.43						
1.45 p. m.	.20	.27	.27	.26	.34	.43	7.1	12.5	2			
2 p. m.	.20	.27	.27	.26	.34	.43						
2.15 p. m.	.20	.27	.27	.26	.34	.43				690	8,064	876
2.30 p. m.	.20	.27	.27	.26	.34	.43						
2.45 p. m.	.20	.27	.27	.26	.34	.43			1½			
3 p. m.	.20	.27	.27	.26	.34	.43						
3.15 p. m.	.18	.27	.27	.26	.34	.43				757	8,697	758
3.30 p. m.	.18	.27	.27	.26	.34	.43						
3.45 p. m.	.18	.27	.27	.26	.34	.46			1			
4 p. m.	.18	.27	.27	.26	.34	.46						
4.15 p. m.	.18	.27	.27	.26	.34	.46				707	8,473	720
4.30 p. m.	.18	.27	.27	.26	.34	.46						
4.45 p. m.	.18	.27	.27	.26	.34	.46			1			
5 p. m.	.18	.27	.27	.26	.34	.46						
5.15 p. m.	.18	.27	.27	.26	.34	.46				696	8,596	722
Average	.20	.28	.265	.27	.35	.45	7.1	12	1.43	720	8,443	849

The burner can not be forced to any considerable extent, as no pressure can be used on the oil which would be sufficient to overcome the drooling.

Three burners used, two large and one small.

Pressure on oil system, 9 pounds.

Total pounds oil burned, 5,758.

Total pounds feed water, 67,543.

Total pounds steam for burners, 6,798.

No. 47.—*Test of oil fuel in a Hohenstein water-tube marine boiler, April 10, 1903.*

[Four hours' duration with 1-inch forced draft, Texas oil, using Booth burner (Santa Fe Railway) under steam].

Time.	Steam pressure by guage.	Temperature of feed.	Calorimeter.			Gauge glass.	Temperature.					Steam pressure on burner, Scotch boiler.
			T₁.	T₂.	Q.		Inside. Dry.	Inside. Wet.	Air in fireroom.	Steam for burner.	Gases at base of stack.	
	Lbs.	° *F.*	° *F.*	° *F.*		*Ins.*	° *F.*	° *F.*	° *F.*	° *F.*	° *F.*	*Lbs.*
10 a. m....	270	120	396	300	0.9835	2	.....	....	99	372	......	90
10.15 a. m.	270	120	398	302	.9840	2	.....	....	100	372	......	90
10.30 a. m.	270	120	396	300	.9835	2.5	84	64	100	372	540	90
10.45 a. m.	275	118	394	300	.9842	2	.....	....	100	370	......	90
11 a. m....	275	128	396	302	.9845	2	.....	....	100	368	......	90
11.15 a. m.	275	124	396	302	.9845	1.5	.....	....	100	376	......	90
11.30 a. m.	275	120	396	302	.9845	1.5	87½	65	100	376	560	90
11.45 a. m.	275	120	400	302	.9825	1	.....	....	102	374	......	90
12 m......	275	118	400	302	.9825	2	.....	....	102	374	......	90
12.15 p. m.	275	118	396	300	.9835	5	.....	....	102	378	......	90
12.30 p. m.	275	118	396	300	.9835	6	89½	65½	102	376	655	90
12.45 p. m.	270	120	396	300	.9835	3	.....	....	102	374	......	90
1 p. m.....	270	120	398	302	.9840	3	.....	....	102	376	......	90
1.15 p. m..	273	119	400	300	.9820	1.5	.....	....	104	378	......	90
1.30 p. m..	275	118	398	302	.9840	1.5	90	66	104	380	555	90
1.45 p. m..	270	120	400	302	.9825	1.75	.....	....	104	378	......	90
2 p. m.....	270	120	398	302	.9840	2	.....	....	104	378	......	90
2.15 p. m..	......	.....	.....	.....	....	......	.....	....	.....	......	......	90
Average ..	273	120	.....	.....	.9836	......	88	65	102	375	578	90

Barometer at noon, 30.09 inches.

Test starts at 10 a. m.; lighted fires at 6 a. m.; 275 pounds steam at 6.50 a. m.; 1-inch forced draft at 9 a. m.

Weather, clear and warm.

Air openings into furnace, 3 □ and 2 ⊙.

Test ends at 2 p. m., owing to lack of fuel oil.

Three burners in use as follows: 3-inch, 2-inch, 3-inch.

No. 47.—*Test of oil fuel in a Hohenstein water-tube marine boiler, April 10, 1903.*

[Four hours' duration with 1-inch forced draft, Texas oil, using Booth burner (Santa Fe Railway), under steam.]

Time.	Pressure on oil system.	Draft pressure.				Flue gases.			Revolutions of fan.	Oil burned per hour.	Feed water per hour.	Steam for burners (feed water, special boiler) per hour.
		Tube chamber.		Above tubes, below drums.	Base of stack.	CO_2.	O.	CO.				
		Front.	Back.									
						P. ct.	*P. ct.*	*P. ct.*		*Lbs.*	*Lbs.*	*Lbs.*
10 a. m....	9	0.28	0.2	−0.1	−0.45	....	....	....	275	.....	.....	.....
10.15 a. m..	9	.28	.2	−.1	−.45	....	....	....	278	.....	.....	.....
10.30 a. m..	9	.28	.2	−.1	−.45	....	....	....	280	.....	.....	.....
10.45 a. m.	9	.28	.2	−.1	−.45	....	....	....	280	.....	.....	.....
11 a. m....	9	.28	.2	−.1	−.45	....	....	....	280	1,270	13,910	805
11.15 a. m..	9	.28	.2	−.1	−.45	....	....	....	280	.....	.....	.....
11.30 a. m..	9	.28	.2	−.1	−.45	5.2	14.0	0	282	.....	.....	.....
11.45 a. m..	9	.28	.2	−.1	−.45	....	....	....	280	.....	.....	.....
12 m......	9	.28	.2	−.1	−.45	....	....	....	280	1,385	15,552	843
12.15 p. m..	9	.28	.2	−.1	−.45	....	....	....	281	.....	.....	.....
12.30 p. m..	10	.28	.2	−.1	−.45	....	....	....	282	.....	.....	.....
12.45 p. m.	10	.28	.2	−.1	−.45	....	....	....	281	.....	.....	.....
1 p. m.....	9	.28	.2	−.1	−.45	....	....	....	280	1,240	14,367	700
1.15 p. m..	9	.28	.2	−.1	−.45	....	....	....	280	.....	.....	.....
1.30 p. m..	9	.28	.2	−.1	−.45	8.2	11.8	.2	280	.....	.....	.....
1.45 p. m..	9	.28	.2	−.1	−.45	....	....	....	281	.....	.....	.....
2 p. m.....	9	.28	.2	−.1	−.45	....	....	....	280	1,350	15,113	800
2.15 p. m..	9	.28	.2	−.1	−.45	....	....	....	280	.....	.....	.....
Average ..	9.1	.28	.2	−.1	−.45	6.7	12.4	.1	280	1,311	14,761	787

Draft pressure in fireroom, 1 inch.
Draft pressure in furnace, 0.6 inch.
Draft pressure in combustion chamber, 0.2 inch.
Total pounds oil burned, 5,245.
Total pounds feed water, 58,942.
Total pounds steam for burners, 3,148.

No. 48.—*Test of oil fuel in a Hohenstein water-tube marine boiler, April 17, 1903.*

[Six hours' duration with natural draft, California oil, using Booth burner (Santa Fe Railway), under steam.]

Time.	Steam pressure by gauge.	Temperature of feed.	Calorimeter.				Temperature.					
			T₁.	T₂.	Q.	Gauge glass.	Inside.		Air in fireroom.	Steam for burner.	Gases at base of stack.	Pressure on oil system.
							Dry.	Wet.				
	Lbs.	° *F.*	° *F.*	° *F.*		*Ins.*	° *F.*	° *F.*	° *F.*	° *F.*	° *F.*	*Lbs.*
11 a. m....	275	122	398	306	0.9805	2	....	....	80	328	......	10
11.15 a. m..	272	119	398	306	.9805	2	....	....	80	336	......	10
11.30 a. m..	276	120	396	306	.9812	2	74	61	80	336	490	10
11.45 a. m..	275	120	398	306	.9805	2.25	....	....	78	336	......	10
12 m......	275	120	398	306	.9805	2	....	....	78	336	......	10
12.15 p. m..	275	120	398	306	.9805	2	....	....	80	334	......	10
12.30 p. m..	276	120	398	306	.9805	2	81½	62	82	336	530	10
12.45 p. m..	275	120	396	306	.9812	2	....	....	82	336	......	10
1 p. m	275	120	396	304	.9800	2	....	....	82	334	......	10
1.15 p. m..	275	118	398	306	.9805	2	....	....	84	334	......	11
1.30 p. m..	276	116	396	306	.9812	2	81	63	84	334	......	11
1.45 p. m..	275	122	394	306	.9820	2	....	....	84	336	......	11
2 p. m	275	122	394	306	.9820	2	....	....	84	336	......	11
2.15 p. m..	275	120	398	306	.9805	2	....	....	88	334	......	11
2.30 p. m..	275	120	398	306	.9805	2.25	82	63½	84	334	......	11
2.45 p. m..	275	122	398	306	.9805	2	....	....	84	334	......	11
3 p. m	275	120	398	306	.9805	2.25	....	....	84	330	......	11
3.15 p. m..	274	120	398	306	.9805	2	....	....	84	330	......	11
3.30 p. m..	275	120	398	306	.9805	2	83	64	86	330	480	11
3.45 p. m..	273	124	398	306	.9805	2	....	....	86	334	......	11
4 p. m	275	118	398	306	.9805	2	...	....	88	334	......	11
4.15 p. m..	274	120	398	306	.9805	2	....	....	86	336	......	11
4.30 p. m..	275	120	398	306	.9805	2	85	65	86	336	......	11
4.45 p. m..	276	124	396	306	.9812	2	....	....	86	334	450	11
5 p. m	275	118	396	306	.9812	2	....	....	88	332	......	10
Average ..	275	120	.....	.....	.9807	.....	81	63	84	334	487	10.6

Barometer at noon, 29.77 inches.
Test started at 11 a. m.; lighted fires at 6.45 a. m.; 275 pounds steam at 8 a. m.
Weather, clear.
Air openings into furnace, 3 ▭ and 2 ⊙.
Heaters as follows in operation: In supply tank, 6–5½ foot lengths with 2–12 foot connections on bottom of tank at suction end; in main surge tank, 10–1 foot 9 inch lengths; in auxilliary surge tank, 2–3 foot lengths—all of 1-inch pipe, using steam at 125 pounds.
Temperature of oil in supply tank at noon, 110° F.

No. 48.—*Test of oil fuel in a Hohenstein water-tube marine boiler, April 17, 1903.*

[Six hours' duration with natural draft, California oil, using Booth burner (Santa Fe Railway), under steam.]

Time.	Draft pressure.						Flue gases.			Oil burned per hour.	Feed water per hour.	Steam for burners (feed-water, special boiler) per hour.
			Tube chamber.									
	Furnace.	Combustion chamber.	Front.	Back.	Above tubes; below drums.	Base of stack.	CO_2.	O.	CO.			
							P. ct.	*P. ct.*	*P. ct.*	*Lbs.*	*Lbs.*	*Lbs.*
11 a. m....	0.15	0.26	0.25	0.25	0.32	0.43				0	0	0
11.15 a. m.	.15	.28	.25	.28	.37	.45						
11.30 a. m.	.15	.27	.24	.27	.35	.45						
11.45 a. m.	.15	.28	.25	.27	.35	.43						
12 m......	.15	.28	.25	.27	.35	.43				800	8,948	835
12.15 p. m.	.15	.28	.25	.27	.35	.45						
12.30 p. m.	.15	.28	.25	.27	.35	.45	8	15	2			
12.45 p. m.	.16	.28	.25	.27	.35	.45						
1 p. m	.16	.28	.25	.27	.35	.45				771	9,000	935
1.15 p. m..	.17	.27	.25	.27	.35	.45						
1.30 p. m..	.16	.27	.23	.25	.35	.45						
1.45 p. m..	.16	.27	.23	.25	.35	.45						
2 p. m	.17	.30	.27	.28	.36	.45				800	8,876	872
2.15 p. m..	.16	.27	.23	.25	.35	.45						
2.30 p. m..	.16	.27	.23	.25	.35	.45						
2.45 p. m..	.15	.27	.23	.25	.35	.45						
3 p. m	.15	.27	.23	.25	.35	.45				704	7,986	878
3.15 p. m..	.17	.27	.24	.26	.33	.42						
3.30 p. m..	.16	.28	.25	.26	.35	.42	7.4	13.2	2.2			
3.45 p. m..	.17	.28	.25	.26	.35	.44						
4 p. m	.17	.28	.25	.26	.35	.45				775	8,616	1,015
4.15 p. m..	.17	.27	.25	.26	.35	.43						
4.30 p. m..	.17	.28	.25	.26	.35	.43						
4.45 p. m..	.17	.27	.25	.26	.35	.43						
5 p. m	.18	.27	.25	.26	.35	.43				721	8,320	823
Average ..	.16	.27	.25	.26	.35	.44	7.7	14.2	2.1	762	8,624	893

About 60 pounds of carbon formed on front part of bridge wall in furnace.
Three burners in use (per cent compare with run of April 9).
Temperature of oil in weigh tank, 110 ° F.
Steam pressure on burner (Scotch boiler), average, 90 pounds.
Total pounds oil burned, 4,571.
Total pounds feed water, 51,746.
Total pounds steam for burners, 5,358.

No. 49.—*Test of oil fuel in a Hohenstein water-tube marine boiler, April 18, 1903.*

[Four hours duration with 1-inch forced draft, California oil, using Booth burner (Santa Fe Railway), under steam.]

Time.	Steam pressure by gauge.	Temperature of feed.	Calorimeter.			Gauge glass.	Temperature.					Pressure on oil system.
							Inside.					
			T₁.	T₂.	Q.		Dry.	Wet.	Air in fireroom.	Steam for burner.	Gases at base of stack.	
	Lbs.	° *F.*	° *F.*	° *F.*		*Ins.*	° *F.*	° *F.*	° *F.*	° *F.*	° *F.*	*Lbs.*
10.15 a. m.	275	120	398	302	0.9840	2	.....	.....	94	328	......	11
10.30 a. m.	275	120	398	302	.9840	2	.....	.....	96	342	......	11
10.45 a. m.	275	124	398	302	.9840	2	82	66	96	346	600	11
11 a. m ...	276	120	398	300	.9825	2	.....	.....	96	348	......	11
11.15 a. m.	275	116	398	300	.9825	2	.....	.....	98	346	......	11
11.30 a. m.	275	120	398	302	.9840	2	.....	.....	98	356	......	11
11.45 a. m.	275	118	396	300	.9835	2	83	65	99	366	560	11
12 m......	275	114	396	300	.9835	1.75	.....	.....	98	356	......	11
12.15 p. m.	273	118	400	300	.9820	2	.....	.....	98	354	......	11
12.30 p. m.	273	120	396	298	.9822	1.5	.....	.....	98	350	......	11
12.45 p. m.	275	119	396	298	.9822	1.5	84	65	98	350	480	11
1 p. m	275	120	396	300	.9835	2	.....	.....	98	356	......	11
1.15 p. m..	276	120	396	298	.9822	2	.....	.....	98	356	......	11
1.30 p. m..	275	118	396	300	.9835	2	.....	.....	98	356	......	11
1.45 p. m..	275	120	396	298	.9822	2	86	66	98	354	500	11
2 p. m	275	124	394	298	.9831	1.5	.....	.....	100	354	......	10
2.15 p. m..	275	118	398	296	.9802	1	.....	.....	100	358	......	10
Average ..	275	119	......	......	.9829	.....	84	65.5	98	352	535	10.9

Test starts at 10.15 a. m.; lighted fires at 6 a. m.; 275 pounds steam at 7.20 a. m.; 1 inch forced draft at 9.15 a. m.

Weather, clear.

Air openings into furnace, 3 □ and 2 ⊙.

Oil heaters in operation as in test No. 48. During the last three hours of this run much oil was observed to burn on the furnace bottom.

About 40 pounds of carbon formed on front of furnace bridge wall.

No. 49.—*Test of oil fuel in a Hohenstein water-tube marine boiler, April 18, 1903.*

[Four hours duration with 1-inch forced draft, California oil, using Booth burner (Santa Fe Railway), under steam.]

Time.	Draft pressure.					Flue gases.			Revolutions of fan.	Oil burned per hour.	Feed water per hour.	Steam for burners (feed water, special boiler), per hour.
	Combustion chamber.	Tube chamber.		Above tubes, below drums.	Base of stack.	CO$_2$.	O.	CO.				
		Front.	Back.									
						P. ct.	*P. ct.*	*P. ct.*		*Lbs.*	*Lbs.*	*Lbs.*
10.15 a. m.	0.25	0.25	−0.2	−0.1	−0.4				280			
10.30 a. m.	.25	.25	−.2	−.1	−.4				281			
10.45 a. m.	.25	.3	−.2	−.1	−.4				280			
11 a. m	.25	.25	−.2	−.1	−.4				280			
11.15 a. m.	.25	.25	−.2	−.1	−.4				281	1,328	13,682	1,245
11.30 a. m.	.25	.25	−.2	−.1	−.4				280			
11.45 a. m.	.25	.25	.2	−.1	−.4	8.2	10.8	0.6	280			
12 m	.25	.25	−.2	−.1	−.4				278			
12.15 p. m.	.25	.25	−.2	−.1	−.4				280	1,368	14,394	933
12.30 p. m.	.25	.25	−.2	−.1	−.4				280			
12.45 p. m.	.25	.25	−.2	−.1	−.4				280			
1 p. m	.25	.25	−.2	−.1	−.4				280			
1.15 p. m	.25	.25	−.2	−.1	−.4				280	1,295	13,808	903
1.30 p. m	.25	.25	−.2	−.1	−.4				280			
1.45 p. m	.25	.25	−.2	−.1	−.4	9	11.2	1.6	281			
2 p. m	.25	.25	−.2	−.1	−.4				280			
2.15 p. m	.25	.25	−.2	−.1	−.4				280	1,222	13,031	935
Average	.25	.2	−.2	−.1	−.4	8.6	11	1.1	280	1,303	13,754	1,004

Three burners in use (to compare with run of April 10).
Steam pressure on burner (Scotch boiler), 90 pounds.
Draft pressure in fireroom, 1 inch.
Draft pressure in furnace, 0.65 inch.
Total pounds oil burned, 5,213.
Total pounds feed water, 54,915.
Total pounds steam for burners, 4,016.

No. 50.—*Test of oil fuel in a Hohenstein water-tube marine boiler, April 20, 1903.*

[Three hours' duration with 3-inch forced draft, California oil, using Booth burner (Santa Fe Railway), under steam.]

Time.	Steam pressure by gauge.	Temperature of feed.	Calorimeter.			Gauge glass.	Temperature.					Steam pressure on burner (Scotch boiler).
							Inside.					
			T₁.	T₂.	Q.		Dry.	Wet.	Air in fire room.	Steam for burner.	Gases at base of stack.	
	Lbs.	*° F.*	*° F.*	*° F.*		*Ins.*	*° F.*	*° F.*	*° F.*	*° F.*	*° F.*	*Lbs.*
12 m......	275	124	396	296	0.9812	2	....	....	96	402	......	90
12.15 p. m.	275	118	396	296	.9812	2.5	....	....	96	408	......	90
12.30 p. m.	275	120	394	294	.9808	1.25	85	68	96	404	[a] 700	90
12.45 p. m.	275	120	394	290	.9785	1	....	....	96	380	......	90
1 p. m.....	275	118	394	286	.9762	1.5	...	....	96	366	......	86
1.15 p. m..	275	118	394	294	.9808	2	....	....	94	368	......	90
1.30 p. m..	274	118	392	296	.9830	2	84	70	96	382	[b] 750	90
1.45 p. m..	275	118	394	296	.9820	2	....	....	98	370	......	90
2 p. m.....	275	114	396	298	.9822	2	....	....	96	362	......	90
2.15 p. m..	275	110	396	300	.9835	3.25	....	....	96	366	......	90
2.30 p. m..	276	116	396	298	.9822	2	84	70	96	360	[b] 780	90
2.45 p. m..	275	120	396	298	.9822	1.75	....	....	96	374	......	90
3 p. m.....	275	112	394	298	.9830	3.25	....	....	96	376	......	90
Average ..	275	117	.....	.....	.9813	.....	84	69	96	378	743	90

[a] Estimated; pyrometer not working; lead melts slowly.

[b] Estimated.

Test started at noon; lighted fires at 6.55 a. m.; 275 pounds steam at 8.20 a. m.; 1-inch forced draft at 10.15 a. m.; 3-inch forced draft at 10.45 a. m.

Weather, overcast.

Air openings into furnace, 3 ▭ and 2 ⊙.

Three burners in use. The burners appear to require constant attention.

No. 50.—*Test of oil fuel in a Hohenstein water-tube marine boiler, April 20, 1903.*

[Three hours' duration with 8-inch forced draft, California oil, using Booth burner (Santa Fe Railway), under steam.]

Time.	Draft pressure.							Smoke.	Fan revolutions per minute.	Oil burned per hour.	Feed water per hour.	Steam for burners (feed water, special boiler) per hour.
	Fire room.	Furnace.	Combustion chamber.	Tube chamber.		Above tubes, below drums.	Base of stack.					
				Front.	Back.							
										Lbs.	*Lbs.*	*Lbs.*
12 m......	3	2.3	1.4	1.4	1.2	0.6	−0.45	....	470	......	......	......
12.15 p. m.	3	2.3	1.3	1.4	1.2	.5	− .45	....	468	......	......	......
12.30 p. m.	3	2.3	1.3	1.4	1.2	.5	− .45	2	470	......	......	......
12.45 p. m.	3	2.3	1.3	1.4	1.2	.5	− .45	....	467	......	......	......
1 p. m.....	3	2.3	1.3	1.4	1.2	.5	− .45	....	465	1,956	19,109	1,124
1.15 p. m..	3	2.3	1.3	1.4	1.2	.5	− .45	....	465	......	......	......
1.30 p. m..	3	2.3	1.3	1.4	1.2	.5	− .45	2	466	......	......	......
1.45 p. m..	3	2.2	1.3	1.4	1.2	.5	− .45	....	460	......	......	......
2 p. m.....	3	2.2	1.3	1.4	1.2	.5	− .45	....	460	2,089	20,392	1,380
2.15 p. m..	3	2.2	1.3	1.4	1.2	.5	− .45	....	460	......	......	......
2.30 p. m..	3	2.2	1.3	1.4	1.2	.5	− .45	1½	460	......	......	......
2.45 p. m..	3	2.2	1.3	1.4	1.2	.5	− .45	....	461	......	......	......
3 p. m.....	3	2.2	1.3	1.4	1.2	.5	− .45	....	458	1,976	19,604	1,374
Average ..	3	2.3	1.3	1.4	1.2	.5	− .45	1.2	464	2,007	19,702	1,293

A deposit of carbon formed on furnace bridge wall as in previous test.
Barometer at noon, 29.66 inches.
Pressure on oil system, 10 pounds.
Total pounds oil burned, 6,021.
Total pounds feed water, 59,105.
Total pounds steam for burners, 3,878.

No. 51.—*Test of oil fuel in a Hohenstein water-tube marine boiler, April 21, 1903.*

[Four hours' duration with 3-inch forced draft, California oil, using Booth burner (Santa Fe Railway), under steam.]

Time.	Steam pressure by gauge.	Temperature of feed.	Calorimeter.			Gauge glass.	Temperature.					Pressure on oil system.
			T_1.	T_2.	Q.		Inside.		Air in fireroom.	Steam for burner.	Gases at base of stack.	
							Dry.	Wet.				
	Lbs.	° *F.*	° *F.*	° *F.*		*Ins.*	° *F.*	° *F.*	° *F.*	° *F.*	° *F.*	*Lbs.*
11 a. m....	267	124	396	296	0. 9812	2. 75	......	.....	90	364	.....	25
11.15 a. m.	269	120	396	296	. 9812	1	......	.....	88	366	.....	25
11.30 a. m.	268	116	396	296	. 9812	1	......	.....	90	370	.....	25
11.45 a. m.	268	120	396	296	. 9812	1	......	.....	90	364	.....	23
12 m......	269	118	396	296	. 9812	2. 75	......	.....	90	370	.....	23
12.15 p. m.	268	118	396	296	. 9812	2	......	.....	90	374	.....	23
12.30 p. m.	267	120	392	294	. 9815	2	82	61	90	370	665	23
12.45 p. m.	265	120	394	296	. 9820	1. 5	......	.....	90	362	.....	23
1 p. m	268	120	396	296	. 9812	2. 75	......	.....	92	360	.....	23
Average ..	268	120	.....	.....	. 9813	.....	82	61	90	366	665	23. 6
3 p. m.....	265	120	394	294	. 9808	2. 5	......	.....	94	366	.....	23
3.15 p. m..	268	120	394	294	. 9808	1. 5	......	.....	94	368	.....	23
3.30 p. m..	266	124	392	294	. 9815	1. 5	83	61	94	368	785	23
3.45 p. m..	265	120	394	294	. 9808	2	......	.....	94	366	.....	23
4 p. m.....	270	120	396	294	. 9800	2. 5	......	.....	94	362	.....	23
4.15 p. m..	270	126	396	294	. 9800	1. 5	......	.....	94	356	.....	23
4.30 p. m..	280	126	394	292	. 9795	1. 75	83	60	94	354	775	23
4.45 p. m..	270	130	396	294	. 9800	1. 5	......	.....	94	358	.....	23
5 p. m.....	274	120	394	292	. 9795	2. 5	......	.....	94	352	.....	23
Average ..	270	123	.....	.....	. 9803	.....	83	60. 5	94	361	780	23
Average both runs	269	121	.....	.....	. 9808	.....	82. 5	61	92	364	722	23

The logs of two tests are combined as one. This set of two tests and the succeeding test are for the purpose of comparing the performance of the different sizes of Booth burners.

First run: Test starts at 11 a. m.; lighted fires at 7 a. m.; 275 pounds steam at 7.55 a. m.; 3-inch forced draft at 10 a. m.; shut down at 2 p. m. One 4-inch burner. Deposit of carbon on bridge wall. Weather clear.

Second run: Test starts at 3 p. m.; lighted fires at 1.40 p. m. One 5-inch burner. Boiler hot from preceding run. 3-inch forced draft. Deposit of carbon on bridge wall. Weather, clear.

Steam pressure on burner (Scotch boiler), 90 pounds.
Draft pressure in fireroom, 3 inches.
Draft pressure in furnace, 2 inches.
Draft pressure in combustion chamber, 1.2 inches.
Total pounds oil burned, 5,812.
Total pounds feed water, 52,432.
Total pounds steam for burners, 3,197.

No. 51.—*Test of oil fuel in a Hohenstein water-tube marine boiler, April 21, 1903.*

[Four hours' duration with 3-inch forced draft, California oil, using Booth burner (Santa Fe Railway), under steam.]

Time.	Draft pressure.				Flue gases.			Smoke.	Revolutions of fan.	Oil burned per hour.	Feed water per hour.	Steam for burners (feed water, special boiler) per hour.
	Tube chamber.		Above tubes, below drums.	Base of stack.	CO$_2$.	O.	CO.					
	Front.	Back.										
					P. ct.	*P. ct.*	*P. ct.*			*Lbs.*	*Lbs.*	*Lbs.*
11 a. m.	1.3	1.1	0.35	−0.45					465			
11.15 a. m.	1.3	1.1	.4	− .45					464			
11.30 a. m.	1.3	1.1	.4	− .45	4	14.2	0.4	1	464			
11.45 a. m.	1.3	1.1	.4	− .45					465			
12 m.	1.3	1.1	.4	− .45					464	1,532	13,965	670
12.15 p. m.	1.3	1.1	.4	− .45					465			
12.30 p. m.	1.3	1.1	.4	− .45				¼	466			
12.45 p. m.	1.3	1.1	.4	− .45					464			
1 p. m.	1.3	1.1	.4	− .45					464	1,480	12,963	668
Average									464	1,506	13,464	669
3 p. m.	1.3	1.1	.4	− .45					455			
3.15 p. m.	1.3	1.1	.4	− .45					456			
3.30 p. m.	1.3	1.1	.4	− .45	5.2	14.4	0	1	455			
3.45 p. m.	1.3	1.1	.4	− .45					455			
4 p. m.	1.3	1.1	.4	− .45					460	1,438	13,034	882
4.15 p. m.	1.3	1.1	.4	− .45					458			
4.30 p. m.	1.3	1.1	.4	− .45				½	456			
4.45 p. m.	1.3	1.1	.4	− .45					458			
5 p. m.	1.3	1.1	.4	− .45					456	1,362	12,470	977
Average									457	1,395	12,752	929
Average both runs	1.3	1.1	.4	− .45	4.6	14.3	0.2	1.37	460	1,450	13,108	799

Air openings into furnace, 2 □ and 20 square inches; middle, ▭ and 276 square inches.
Barometer at noon, 29.7 inches.

No. 52.—*Test of oil fuel in a Hohenstein water-tube marine boiler, April 22, 1903.*

[Two hours' duration with 3-inch forced draft, California oil, using Booth burner (Santa Fe Railway), under steam.]

Time.	Steam pressure by gauge.	Temperature of feed.	Calorimeter.			Gauge glass.	Temperature.					Steam pressure on burner (Scotch boiler).
							Inside.					
			T_1.	T_2.	Q.		Dry.	Wet.	Air in fireroom.	Steam for burner.	Gases at base of stack.	
	Lbs.	° *F.*	° *F.*	° *F.*		*Ins.*	° *F.*	° *F.*	° *F.*	° *F.*	° *F.*	*Lbs.*
11 a. m.	268	120	396	294	0.9800	1.5	.....	.....	86	366	......	90
11.15 a. m.	267	120	394	292	.9795	1.5	.....	.....	86	366	......	90
11.30 a. m.	268	120	396	294	.9800	1.5	77½	59½	86	360	760	90
11.45 a. m.	270	118	394	292	.9795	1.5	.....	.....	86	360	......	90
12 m.	275	120	396	294	.9800	1.5	.....	.....	88	358	......	90
12.15 p. m.	270	124	392	292	.9805	1.5	.....	.....	88	360	......	90
12.30 p. m.	268	118	396	292	.9790	1.5	78	59	88	360	775	90
12.45 p. m.	268	120	394	292	.9795	1.5	.....	.....	90	364	......	90
1 p. m.	266	120	394	292	.9795	1.5	.....	.....	88	360	......	90
Average	269	120	.....	.....	.9797	.....	78	59	87	362	767	90

Barometer at noon, 29.81 inches.

Test starts at 11 a. m.; lighted fires at 7 a. m.; 275 pounds steam at 7.50 a. m.; 3-inch forced draft at 10 a. m.

Weather, clear.

Air opening into furnaces, 2 □ and 20 square inches.

Deposit of carbon on bridge wall and on false bottom to within 6 inches of burner, demonstrating that oil was not well sprayed, i. e., not sufficiently atomized during the last hour.

No. 52.—*Test of oil fuel in a Hohenstein water-tube marine boiler, April 22, 1903.*

[Two hours' duration with 3-inch forced draft, California oil, using Booth burner (Santa Fe Railway), under steam.]

Time.	Draft pressure.							Smoke.	Revolutions of fan.	Oil burned per hour.	Feed water per hour.	Steam for burners (feed water, special boiler) per hour.
	Fireroom.	Furnace.	Combustion chamber.	Tube chamber.		Above tubes, below drums.	Base of stack.					
				Front.	Back.							
										Lbs.	*Lbs.*	*Lbs.*
11 a. m....	3	1.95	1	1.2	1	0.45	—0.25	.....	458	......	....	......
11.15 a. m.	3	1.95	1	1.2	1	.45	— .25	.....	456	......	....	......
11.30 a. m.	3	1.95	1	1.2	1	.45	— .25	¾	456	......	....	......
11.45 a. m.	3	1.95	1	1.2	1	.45	— .25	.....	458	......	....	......
12 m......	3	1.95	1	1.2	1	.45	— .35	.....	456	1,348	12,150	879
12.15 p. m.	3	1.95	1	1.2	1	.45	— .45	.....	456	......	....	......
12.30 p. m.	3	1.95	1	1.2	1	.45	— .45	1.	456	......	....	......
12.45 p. m.	3	1.95	1	1.2	1	.45	— .45	.....	458	......	....	......
1 p. m.....	3	1.95	1	1.2	1	.45	— .45	.....	456	1,408	12,478	740
Average...	3	1.95	1	1.2	1	.45	— .35	.88	457	1,378	12,314	809

One 3-inch burner in use.
Pressure on oil system, 23 pounds.
Total pounds oil burned, 2,756.
Total pounds feed water, 24,628.
Total pounds steam for burners, 1,619.

No. 53.—*Test of oil fuel in a Hohenstein water-tube marine boiler, April 23, 1903.*

[Three hours' duration with 3-inch forced draft, California oil, using Booth burner (Sante Fe Railway), under steam.]

Time.	Steam pressure by gauge.	Temperature of feed.	Calorimeter.			Gauge glass.	Temperatures.					Steam pressure on burner (Scotch boiler).
							Inside.					
			T_1.	T_2.	Q.		Dry.	Wet.	Air in fire room.	Steam for burner.	Gases at base of stack.	
	Lbs.	° *F.*	° *F.*	° *F.*		*Ins.*	° *F.*	° *F.*	° *F.*	° *F.*	° *F.*	*Lbs.*
11 a. m ...	265	122	394	296	0.9820	1	....	....	86	350	......	91
11.15 a. m.	274	124	394	296	.9820	1	....	....	86	354	......	90
11.30 a. m.	264	120	394	296	.9820	1.25	75	57½	86	356	775	90
11.45 a. m.	240	120	394	296	.9820	1	....	....	86	350	......	90
12 m......	264	116	396	294	.9800	1	....	....	86	356	......	90
12.15 p. m.	268	122	394	294	.9808	1	....	....	86	356	......	90
12.30 p. m.	270	120	396	294	.9800	1.5	76½	57½	86	358	800	90
12.45 p. m.	265	120	394	294	.9808	1	....	....	88	362	......	90
1 p. m	265	120	392	294	.9815	1	....	....	86	360	......	90
Average ..	264	120	.....	.....	.9812	.....	76	57½	86.2	356	788	90

Test starts at 11 a. m.; lighted fires at 7.05 a. m.; 275 pounds steam at 7.55 a. m.; 3-inch forced draft at 10 a. m.
Weather, partly cloudy.
Air openings into furnace, 3 □ and 40 square inches.
One 2-inch burner in use.

No. 53.—*Test of oil fuel in a Hohenstein water-tube marine boiler, April 23, 1903.*

[Three hours' duration with 3-inch forced draft, California oil, using Booth burner (Sante Fe Railway), under steam.]

Time.	Pressure on oil system.	Draft pressure.							Revolutions of fan.	Oil burned per hour.	Feed water per hour.	Steam for burners (feed water, special boiler) per hour.
		Fireroom.	Furnace.	Combustion chamber.	Tube chamber.		Above tubes, below drums.	Base of stack.				
					Front.	Back.						
	Lbs.									*Lbs.*	*Lbs.*	*Lbs.*
11 a. m....	20	3	1.9	1.15	1.2	1.1	0.4	—0.35	456	......	....	......
11.15 a. m.	26	3	1.95	1.15	1.2	1.1	.45	— .45	458	......	....	......
11.30 a. m.	26	3	1.9	1.1	1.2	1.1	.4	— .45	456	......	....	......
11.45 a. m.	26	3	1.95	1.15	1.2	1.1	.4	— .45	456	......	....	......
12 m......	26	3	1.95	1.1	1.2	1.1	.4	— .45	456	1,373	11,243	678
12.15 p. m.	26	3	1.95	1.1	1.2	1.1	.4	— .45	456	......	....	......
12.30 p. m.	26	3	1.95	1.1	1.2	1.1	.4	— .45	456	......	....	......
12.45 p. m.	26	3	1.95	1.1	1.2	1.1	.4	— .45	456	......	....	......
1 p. m	26	3	1.95	1.1	1.2	1.1	.4	— .45	456	1,275	10,889	703
Average ..	25.4	3	1.95	1.12	1.2	1.1	.4	— .44	456	1,323	11,066	690

Barometer at noon, 29.9 inches.
Total pounds oil burned, 2,645.
Total pounds feed water, 22,132.
Total pounds steam for burner, 1,381.

No. 54.—*Test of oil fuel in a Hohenstein water-tube marine boiler, April 24, 1903.*

[Three hours' duration with 3-inch forced draft, California oil, using Booth burner (Santa Fe Railway), under steam.]

Time.	Steam pressure by gauge.	Temperature of feed.	Calorimeter.			Gauge glass.	Temperature.					Steam pressure on burner (Scotch boiler).
			T_1.	T_2.	Q.		Inside.		Air in fireroom.	Steam for burner.	Gases at base of stack.	
							Dry.	Wet.				
	Lbs.	° *F.*	° *F.*	° *F.*		*Ins.*	° *F.*	° *F.*	° *F.*	° *F.*	° *F.*	*Lbs.*
2 p. m....	262	126	392	296	0.9830	1	......	....	98	376	......	90
2.15 p. m..	260	120	396	296	.9812	1.5	......	....	96	376	......	90
2.30 p. m..	264	120	396	296	.9812	1.5	85	62	96	376	855	90
2.45 p. m..	265	124	400	296	.9795	1.5	......	....	97	374	......	90
3 p. m....	268	124	398	296	.9805	1	......	....	96	368	......	90
3.15 p. m..	265	118	400	296	.9795	1.5	......	....	96	388	......	90
3.30 p. m..	268	120	400	296	.9795	1.5	85	62	96	368	840	90
3.45 p. m..	273	124	400	296	.9795	1.5	.....	....	96	366	......	90
4 p. m....	268	118	400	296	.9795	1.5	......	....	96	362	......	90
4.15 p. m..	265	118	398	296	.9805	2.5	......	....	96	372	......	90
4.30 p. m..	268	118	398	296	.9805	1	87	62	96	378	905	90
4.45 p. m..	270	116	400	296	.9795	1.5	......	....	96	376	......	90
5 p. m....	270	120	400	296	.9795	2.5	......	....	96	382	......	90
Average ..	267	120	.....	.....	.9803	.....	85.7	62	96	374	867	90

Test starts at 2 p. m.; lighted fires at 7 a. m.; boiler under steam during forenoon; forced draft at 1 p. m.; 3-inch forced draft at 1.30 p. m.

Weather, clear.

Air openings into furnace, 3 □ and 3 ⊙.

Pass-over valves on burners were kept slightly cracked during first two hours, thus admitting steam into oil passages. This by direction of the representative of the Santa Fe.

No. 54.—*Test of oil fuel in a Hohenstein water-tube marine boiler, April 24, 1903.*

[Three hours' duration with 3-inch forced draft, California oil, using Booth burner (Santa Fe Railway), under steam.]

Time.	Draft pressure.							Smoke.	Revolutions of fan.	Oil burned per hour.	Feed water per hour.	Steam for burners (feed water, special boiler) per hour.
	Fireroom.	Furnace.	Combustion chamber.	Tube chamber.		Above tubes, below drums.	Base of stack.					
				Front.	Back.							
										Lbs.	*Lbs.*	*Lbs.*
2 p. m	3	2.2	1.2	1.3	1.1	0.45	−0.45	....	458	......	......	......
2.15 p. m	3	2.2	1.2	1.3	1.15	.45	− .45	....	456	......	......	......
2.30 p. m	3	2.2	1.2	1.3	1.15	.45	− .45	1	456	......	......	......
2.45 p. m	3	2.2	1.25	1.3	1.15	.45	− .45	....	458	......	......	......
3 p. m	3	2.2	1.2	1.3	1.15	.45	− .45	....	458	1,514	13,405	1,045
3.15 p. m	3	2.2	1.2	1.3	1.2	.5	− .45	....	458	......	......	......
3.30 p. m	3	2.2	1.2	1.3	1.2	.5	− .45	1½	460	......	......	......
3.45 p. m	3	2.2	1.2	1.3	1.2	.5	− .45	....	458	......	......	......
4 p. m	3	2.2	1.2	1.3	1.2	.5	− .45	....	458	1,396	11,420	775
4.15 p. m	3	2.2	1.2	1.3	1.2	.5	− .45	....	456	......	......	......
4.30 p. m	3	2.2	1.2	1.3	1.2	.5	− .45	½	456	......	......	......
4.45 p. m	3	2.2	1.2	1.3	1.2	.5	− .45	....	456	......	......	......
5 p. m	3	2.2	1.2	1.3	1.2	.5	− .45	....	458	1,837	15,938	882
Average	3	2.2	1.2	1.3	1.17	.48	− .45	....	457	1,582	13,588	901

Three burners in use. Right-hand burner not under full action; apparently clogged.
Barometer at noon, 30.05 inches.
Total pounds oil burned, 4,747.
Total pounds feed water, 40,763.
Total pounds steam for burners, 2,702.

No. 55.—*Test of oil fuel in a Hohenstein water-tube marine boiler, April 27, 1903.*

[Four hours' duration with natural draft, using Macdonald burner, under steam.]

Time.	Steam pressure by gauge.	Temperature of feed.	Calorimeter.			Gauge glass.	Temperature.					
							Inside.					
			T_1.	T_2.	Q.		Dry.	Wet.	Air in fireroom.	Oil in weighing tank.	Steam or air for burner	Gases at base of stack.
	Lbs.	° *F.*	° *F.*	° *F.*		*Ins.*	° *F.*	° *F.*	° *F.*	° *F.*	° *F.*	° *F.*
12.30 p. m.	265	122	398	302	0.9840	2	.....	.....	88	......	322	.....
12.45 p. m.	262	110	400	306	.9855	2	.....	.....	88	......	320	.....
1 p. m	265	120	400	308	.9870	2	85.5	66.5	90	160	320	620
1.15 p. m..	268	120	400	308	.9870	2	.....	.....	92	......	322	.....
1.30 p. m..	265	118	400	308	.9870	2	.....	.....	92	......	322	.....
1.45 p. m..	264	124	406	308	.9843	2	.....	.....	92	......	324	.....
2 p. m	262	124	402	306	.9850	2	92.0	69.0	94	160	322	550
2.15 p. m..	270	120	404	308	.9852	2	.....	.....	94	......	326	.....
2.30 p. m..	270	118	402	308	.9860	2	.....	.....	94	......	326	.....
2.45 p. m..	268	118	406	308	.9843	2	.....	.....	94	......	326	.....
3 p. m	260	122	406	308	.9843	2	91.0	65.0	94	160	328	560
3.15 p. m..	265	120	406	308	.9843	2	.....	.....	94	......	326	.....
3.30 p. m..	263	120	406	308	.9843	2	.....	.....	95	......	326	.....
3.45 p. m..	265	120	406	308	.9843	2	.....	.....	95	......	326	.....
4 p. m	265	120	404	308	.9852	2	91.5	70.0	96	160	328	555
4.15 p. m..	265	120	406	308	.9843	2	.....	.....	97	......	328	.....
4.30 p. m..	265	118	406	308	.9843	2	.....	.....	97	......	328	.....
Average ..	265	119.6	.....	.....	.9850	.....	90	67.6	93	160	325	571

Test starts at 12.30 p. m.; lighted fires at 7 a. m.; 275 pounds steam at 7.50 a. m.

The test was delayed in starting by the clogging of all the burners at about 11 a. m., necessitating their withdrawal.

Weather clear.

Air openings to furnace, 8 □ and 8 ⊙.

No. 55.—*Test of oil fuel in a Hohenstein water-tube marine boiler, April 27, 1903.*

[Four hours' duration with natural draft, using Macdonald burner, under steam.]

Time.	Steam pressure on burner (Scotch boiler).	Pressure on oil system.	Draft pressure.						Smoke.	Oil burned per hour.	Feed water per hour.	Steam for burners (feed water, special boiler) per hour.
			Furnace.	Combustion chamber.	Tube chamber.		Above tubes, below drums.	Base of stack.				
					Front.	Back.						
	Lbs.	*Lbs.*								*Lbs.*	*Lbs.*	*Lbs.*
12.30 p. m.	90	40	0.14	0.24	0.23	0.24	0.33	0.40	....	......	......	......
12.45 p. m.	90	40	.13	.27	.24	.27	.37	.45	....	......	......	......
1 p. m	90	40	.14	.27	.24	.27	.36	.45	1	......	......	......
1.15 p. m..	90	40	.14	.27	.24	.27	.36	.45	....	......	......	......
1.30 p. m..	90	40	.14	.27	.24	.27	.36	.45	....	891	10,229	1,264
1.45 p. m..	90	40	.14	.27	.24	.27	.36	.45	....	......	......	......
2 p. m	90	40	.14	.27	.24	.27	.36	.45	1	......	......	......
2.15 p. m..	90	40	.14	.27	.24	.27	.36	.45	....	......	......	......
2.30 p. m..	90	40	.14	.27	.24	.27	.36	.45	....	875	9,723	1,057
2.45 p. m..	90	40	.14	.27	.24	.27	.36	.45	....	......	......	......
3 p. m	90	40	.15	.27	.24	.27	.37	.45	¾	......	......	......
3.15 p. m..	90	40	.14	.27	.24	.27	.37	.45	....	......	......	......
3.30 p. m..	90	40	.14	.27	.24	.27	.37	.45	....	858	9,694	959
3.45 p. m..	90	40	.15	.27	.24	.27	.37	.45	....	......	......	......
4 p. m	90	40	.14	.27	.24	.27	.37	.45	1¼	......	......	......
4.15 p. m..	90	40	.14	.27	.24	.27	.37	.45	....	......	......	......
4.30 p. m..	90	40	.14	.27	.24	.27	.37	.45	....	821	9,590	960
Average ..	90	40	.14	.27	.24	.27	.363	.45	1	861	9,809	1,060

Toward end of test burners clogged considerably.
Total pounds oil burned, 3,445.
Total pounds feed water, 39,236.
Total pounds steam for burners, 4,240.

No. 56.—*Test of oil fuel in a Hohenstein water-tube marine boiler, May 4, 1903.*

[Four hours' duration with natural draft, California oil, using Oil City burner, under steam.]

Time.	Steam pressure by gauge.	Temperature of feed water.	Calorimeter.			Gauge glass.	Temperature.					
			T$_1$.	T$_2$.	Q.		Inside.		Air in fireroom.	Oil in weighing tank.	Steam or air for burner.	Gases at base of stack.
							Dry.	Wet.				
	Lbs.	° *F.*	° *F.*	° *F.*		*Ins.*	° *F.*	° *F.*	° *F.*	° *F.*	° *F.*	° *F.*
11.15 a. m.	270	110	404	306	0.9840	1.75	.....	.....	82	.....	328	.....
11.30 a. m.	265	110	404	306	.9840	2	.....	.....	88	.....	332	.....
11.45 a. m.	260	112	406	306	.9830	2	83	66	88	160	332	575
12 m......	267	120	406	306	.9830	1.75	.....	.....	86	.....	332	.....
12.15 p. m.	270	124	406	306	.9830	2.25	.....	.....	86	.....	328	.....
12.30 p. m.	260	120	404	306	.9840	2.75	.....	.....	90	.....	328	.....
12.45 p. m.	270	120	404	306	.9840	2.75	83½	65	88	160	328	560
1 p. m	265	120	406	306	.9830	2.25	.....	.....	90	.....	328	.....
1.15 p. m..	270	120	406	306	.9830	2.5	.....	.....	88	.....	330	.....
1.30 p. m..	268	120	406	306	.9830	1.75	.....	.....	90	.....	332	.....
1.45 p. m..	270	120	406	309	.9830	1.75	83	68	86	160	332	580
2 p. m	268	120	404	304	.9828	1.5	.....	.....	86	.....	330	.....
2.15 p. m..	270	120	406	306	.9830	1.75	.....	.....	88	.....	334	.....
2.30 p. m..	268	120	404	306	.9840	1.5	.....	.....	88	.....	338	.....
2.45 p. m..	267	120	406	306	.9830	1.5	85½	69½	90	160	336	600
3 p. m	263	120	406	306	.9830	1.5	.....	.....	86	.....	336	.....
3.15 p. m..	270	120	406	306	.9830	1.75	.....	.....	86	.....	336	.....
Average ..	267	119	.....	.....	.9834	.....	84	67	88	160	332	579

Test starts at 12.15 p. m.; lighted fires at 6 a. m.: 275 pounds steam at 7.10 a. m.
The test was delayed by trouble in heating the oil.
Weather, clear.
Air openings into furnace, 8 □ and 100 square inches.

No. 56.—*Test of oil fuel in a Hohenstein water-tube marine boiler, May 4, 1903.*

[Four hours' duration with natural draft, California oil, using Oil City burner, under steam.]

Time.	Steam pressure on burner (Scotch boiler).	Pressure on oil system.	Draft pressure.						Smoke.	Oil burned per hour.	Feed water per hour.	Steam for burners (feed water, special boiler) per hour.
			Furnace.	Combustion chamber.	Tube chamber.		Above tubes, below drums.	Base of stack.				
					Front.	Back.						
	Lbs.	*Lbs.*								*Lbs.*	*Lbs.*	*Lbs.*
11.15 a. m.	91	40	0.15	0.27	0.24	0.27	0.35	0.46	.....	......	......	......
11.30 a. m.	90	40	.15	.27	.24	.27	.35	.45	.....	......	......	......
11.45 a. m.	90	40	.15	.27	.25	.27	.36	.45	1	......	......	......
12 m......	90	40	.15	.27	.25	.27	.36	.45	.....	......	......	......
12.15 p. m.	90	40	.15	.27	.25	.27	.36	.46	.....	855	9,616	704
12.30 p. m.	90	40	.15	.27	.25	.27	.36	.46	.....	......	......	......
12.45 p. m.	90	40	.15	.29	.26	.28	.36	.46	1	......	......	......
1 p. m....	90	40	.15	.29	.26	.28	.36	.46	.....	......	......	......
1.15 p. m..	90	40	.15	.27	.25	.27	.35	.46	.....	794	9,089	760
1.30 p. m..	90	40	.15	.27	.25	.27	.36	.46	.....	......	......	......
1.45 p. m..	90	40	.15	.27	.25	.27	.36	.46	1	......	......	......
2 p. m....	90	40	.15	.27	.25	.27	.38	.48	.....	......	......	......
2.15 p. m..	90	40	.15	.27	.25	.27	.38	.48	.....	866	9,365	732
2.30 p. m..	90	40	.15	.27	.25	.27	.38	.48	.....	......	......	......
2.45 p. m..	90	40	.15	.27	.25	.27	.38	.48	¾	......	......	......
3 p. m....	90	40	.15	.27	.25	.27	.36	.48	.....	......	......	......
3.15 p. m..	90	40	.15	.27	.25	.27	.36	.48	.....	765	8,525	730
Average ..	90	40	.15	.27	.25	.27	.36	.46	.94	820	9,149	731

Six burners in use.
Total pounds oil burned, 3,280.
Total pounds feed water, 36,595.
Total pounds steam for burners, 2,926.

No. 57.—*Test of oil fuel in a Hohenstein water-tube marine boiler, May 5, 1903.*

[Six hours duration with natural draft, using Oil City burner, under steam.]

Time.	Steam pressure by gauge.	Temperature of feed.	Calorimeter.			Gauge glass.	Temperature.					Steam pressure on burner (Scotch boiler).
			T₁.	T₂.	Q.		Inside.		Air in fireroom.	Steam or air for burner.	Gases at base of stack.	
							Dry.	Wet.				
	Lbs.	° *F.*	° *F.*	° *F.*		*Ins.*	° *F.*	° *F.*	° *F.*	° *F.*	° *F.*	*Lbs.*
10 a. m ...	270	120	404	304	0.9828	1	.....	.....	82	334	.....	90
10.15 a. m.	260	110	404	304	.9828	1.5	.....	.....	88	336	.....	90
10.30 a. m.	270	122	404	306	.9840	1.5	85	68	86	336	640	90
10.45 a. m.	270	120	406	306	.9830	1	.....	.....	86	338	.....	90
11 a. m ...	265	120	404	304	.9828	1	.....	.....	86	338	.....	90
11.15 a. m.	268	118	406	306	.9830	1	.....	.....	86	338	.....	90
11.30 a. m.	265	120	406	306	.9830	1	84½	66½	92	342	590	90
11.45 a. m.	266	120	404	306	.9840	1	.....	.....	88	344	.....	90
12 m......	265	122	404	306	.9840	1.5	.....	.....	88	344	.....	90
12.15 p. m.	268	120	404	306	.9840	1.5	.....	.....	86	344	.....	90
12.30 p. m.	265	120	406	306	.9830	1.5	86½	68	86	340	600	90
12.45 p. m.	270	120	406	306	.9830	1.5	.....	.....	90	340	.....	90
1 p. m	270	120	406	306	.9830	1.5	.....	.....	90	340	.....	90
1.15 p. m..	265	122	404	304	.9828	1.5	.....	.....	90	340	.....	90
1.30 p. m..	270	120	404	304	.9828	1.5	91	70	90	342	580	90
1.45 p. m..	268	120	404	302	.9815	1.5	.....	.....	88	344	.....	90
2 p. m	273	120	404	304	.9828	1.5	.....	.....	90	342	.....	90
2.15 p. m..	270	124	406	306	.9830	1	.....	.....	92	344	.....	90
2.30 p. m..	268	120	406	306	.9830	1	89	69	90	342	600	90
2.45 p. m..	265	120	404	304	.9828	1	.....	.....	90	340	.....	90
3 p. m	265	120	404	304	.9828	1	.....	.....	90	340	.....	90
3.15 p. m..	265	120	404	304	.9828	1	.....	.....	88	340	.....	90
3.30 p. m..	273	120	404	304	.9828	1	88	70	88	340	590	90
3.45 p. m..	266	120	404	304	.9828	1	.....	.....	89	340	.....	90
4 p. m	268	118	404	304	.9828	1	.....	.....	88	340	.....	90
Average ..	267	120	.....	.....	.9830	.....	87	68	88	340	600	90

Test starts at 11 a. m.
Boiler contained 5 gallons of Emerald oil overnight.
Blown out and refilled in morning.
Weather, clear.
Air openings into furnace = 3 ▭ and 100 square inches.
Six burners in use.

No. 57.—*Test of oil fuel in a Hohenstein water-tube marine boiler, May 5, 1903.*

[Six hours duration with natural draft, using Oil City burner, under steam.]

Time.	Draft pressure.						Flue gases.			Oil burned per hour.	Feed water per hour.	Steam for burners (feed water, special boiler) per hour.
	Furnace.	Combustion chamber.	Tube chamber.		Above tubes below drums.	Base of stack.	CO_2.	O.	CO.			
			Front.	Back.								
							P. ct.	*P. ct.*	*P. ct.*	*Lbs.*	*Lbs.*	*Lbs.*
10 a. m ...	0. 16	0. 27	0. 24	0. 27	0. 36	0. 47	.....	.....	.....	.....	.....	.....
10.15 a. m.	. 17	. 28	. 25	. 28	. 37	. 46	.....	.....	.....	.....	.....	.....
10.30 a. m.	. 17	. 28	. 25	. 28	. 37	. 47	.....	.....	.....	.....	.....	.....
10.45 a. m.	. 17	. 28	. 25	. 28	. 37	. 47	.....	.....	.....	.....	.....	.....
11 a. m ...	. 17	. 28	. 25	. 28	. 37	. 47	.....	.....	.....	850	9, 482	810
11.15 a. m.	. 16	. 28	. 25	. 28	. 37	. 47	.....	.....	.....	.....	.....	.....
11.30 a. m.	. 16	. 28	. 25	. 28	. 37	. 47	6. 4	10. 8	0	.....	.....	.....
11.45 a. m.	. 16	. 28	. 25	. 28	. 37	. 47	.....	.....	.....	.....	.....	.....
12 m......	. 16	. 28	. 25	. 28	. 37	. 47	.....	.....	.....	864	9, 787	776
12.15 p. m.	. 16	. 28	. 25	. 28	. 37	. 47	.....	.....	.....	.....	.....	.....
12.30 p. m.	. 16	. 28	. 25	. 28	. 37	. 47	.....	.....	.....	.....	.....	.....
12.45 p. m.	. 16	. 28	. 25	. 28	. 37	. 47	.....	.....	.....	.....	.....	.....
1 p. m	. 16	. 28	. 25	. 28	. 37	. 47	.....	.....	.....	900	10, 034	815
1.15 p. m..	. 16	. 28	. 24	. 26	. 35	. 46	.....	.....	.....	.....	.....	.....
1.30 p. m..	. 16	. 26	. 24	. 26	. 35	. 46	7	11	. 4	.....	.....	.....
1.45 p. m..	. 16	. 26	. 24	. 26	. 35	. 46	.....	.....	.....	.....	.....	.....
2 p. m	. 16	. 27	. 25	. 26	. 35	. 45	.....	.....	.....	861	9, 891	791
2.15 p. m..	. 16	. 27	. 24	. 26	. 35	. 45	.....	.....	.....	.....	.....	.....
2.30 p. m..	. 16	. 27	. 24	. 26	. 35	. 46	.....	.....	.....	.....	.....	.....
2.45 p. m..	. 16	. 27	. 24	. 26	. 35	. 46	.....	.....	.....	.....	.....	.....
3 p. m	. 16	. 27	. 24	. 26	. 35	. 46	.....	.....	.....	818	9, 359	765
3.15 p. m..	. 16	. 27	. 24	. 26	. 35	. 46	.....	.....	.....	.....	.....	.....
3.30 p. m..	. 16	. 27	. 24	. 26	. 35	. 46	.....	.....	.....	.....	.....	.....
3.45 p. m..	. 16	. 27	. 24	. 26	. 35	. 46	.....	.....	.....	.....	.....	.....
4 p. m	. 16	. 27	. 24	. 26	. 35	. 46	.....	.....	.....	838	9, 711	780
Average ..	. 16	. 27	. 245	. 27	. 36	. 46	6. 7	10. 9	. 2	855	9, 711	790

Temperature of oil in weigh tank, 160° F.
Pressure on oil system, 21 pounds.
Total pounds oil burned, 5,131.
Total pounds feed water, 58,264.
Total pounds steam for burners, 4,737.

No. 58.—*Test of oil fuel in a Hohenstein water-tube marine boiler, May 6, 1903.*

[Five hours' duration with 1-inch forced draft, using Oil City burner, under steam.]

Time.	Steam pressure by gauge.	Temperature of feed.	Calorimeter.			Gauge glass.	Temperature.					Steam pressure on burner.
			T_1	T_2	Q.		Inside.		Air in fireroom.	Steam or air for burner.	Gases at base of stack.	
							Dry.	Wet.				
	Lbs.	° *F.*	° *F.*	° *F.*		*Ins.*	° *F.*	° *F.*	° *F.*	° *F.*	° *F.*	*Lbs.*
11 a. m....	270	118	400	300	0.9820	1.25	.....	.....	96	370	.....	90
11.15 a. m.	265	120	402	300	.9815	1	.....	.....	98	370	.....	90
11.30 a. m.	275	120	402	300	.9815	1	94	70	98	372	795	90
11.45 a. m.	270	120	402	300	.9815	1.25	.....	.....	108	374	.....	90
12 m......	275	120	400	300	.9820	1.25	.....	.....	106	370	.....	90
12.15 p. m.	270	120	402	300	.9815	1	.....	.....	108	370	.....	90
12.30 p. m.	270	120	402	300	.9815	1	95	69	108	374	800	90
12.45 p. m.	273	118	402	300	.9815	1.25	.....	.....	108	372	.....	90
1 p. m	274	120	402	300	.9815	1.5	.....	.....	110	374	.....	90
1.15 p. m..	270	120	400	300	.9820	1.25	.....	.....	110	370	.....	90
1.30 p. m..	270	120	400	300	.9820	1.25	98	70	110	370	795	90
1.45 p. m..	268	120	400	300	.9820	1.25	.....	.....	110	378	.....	90
2 p. m.....	270	120	400	300	.9820	1.25	.....	.....	111	380	.....	90
2.15 p. m..	260	120	400	300	.9820	1	.....	.....	111	378	.....	90
2.30 p. m..	270	120	402	300	.9815	1.25	98½	70	110	378	780	90
2.45 p. m..	265	120	400	300	.9820	1	.....	.....	110	376	.....	90
3 p. m.....	268	118	400	300	.9820	1.25	.....	.....	112	378	.....	90
3.15 p. m..	268	120	400	300	.9820	1.25	.....	.....	112	376	.....	90
3.30 p. m..	260	120	402	300	.9815	1.25	99	71	112	374	790	90
3.45 p. m..	272	120	402	300	.9815	1	.....	.....	111	380	.....	90
4 p. m.....	270	120	402	300	.9815	1.25	.....	.....	112	380	.....	90
Average ..	269	120	.....	.....	.9817	......	97	70	108	375	792	90

Test starts at 11 a. m.; lighted fires at 7 a. m.; 275 pounds steam at 8.15 a. m.; 1-inch forced draft at 10 a. m.
Weather, clear. Barometer at noon, 30.16 inches.
Six Oil City Boiler Works burners at $\frac{3}{16}$ inch opening.
Air openings into furnace, 3 ☐ and 100 square inches.
Temperature of oil in weigh tank, 160° F.

No. 58.—*Test of oil fuel in a Hohenstein water-tube marine boiler, May 6, 1903.*

[Five hours' duration with 1-inch forced draft, using Oil City burner, under steam.]

Time.	Draft pressure.					Flue gases.			Revolutions of fan.	Oil burned per hour.	Feed water per hour.	Steam for burners (feed water, special boiler) per hour.
	Furnace.	Tube chamber.		Above tubes below drums.	Base of stack.	CO_2.	O.	CO.				
		Front.	Back.									
						P. ct.	*P. ct.*	*P. ct.*		*Lbs.*	*Lbs.*	*Lbs.*
11 a. m....	0.6	0.30	0.25	—0.05	—0.4	.....	.....	.....	279	......	......	......
11.15 a. m.	.6	.30	.25	— .05	— .4	.....	.....	.....	278	......	......	......
11.30 a. m.	.6	.30	.25	— .05	— .4	.....	.....	.....	285	......	......	......
11.45 a. m.	.7	.30	.25	— .05	— .4	.....	.....	.....	286	......	......	......
12 m......	.6	.30	.25	— .05	— .4	.....	.....	.....	290	1,362	14,180	776
12.15 p. m.	.6	.30	.25	— .05	— .4	.....	.....	.....	290	......	......	......
12.30 p. m.	.6	.30	.25	— .05	— .4	6.2	12.8	0.4	288	......	......	......
12.45 p. m.	.6	.30	.25	— .05	— .4	.....	.....	.....	289	......	......	......
1 p. m	.6	.30	.25	— .05	— .4	.....	.....	.....	290	1,464	15,425	815
1.15 p. m..	.6	.30	.25	— .05	— .4	.....	.....	.....	289	......	......	......
1.30 p. m..	.6	.30	.25	— .05	— .4	.....	.....	.....	288	......	......	......
1.45 p. m..	.6	.30	.25	— .05	— .4	.....	.....	.....	289	......	......	......
2 p. m	.6	.30	.25	— .05	— .4	.....	.....	.....	289	1,443	15,256	755
2.15 p. m..	.6	.30	.25	— .05	— .4	.....	.....	.....	288	......	......	......
2.30 p. m..	.6	.30	.25	— .05	— .4	8.2	10	.2	288	......	.....	......
2.45 p. m..	.6	.30	.25	— .05	— .4	.....	.....	.....	288	......	......	......
3 p. m	.6	.30	.25	— .05	— .4	.....	.....	.....	289	1,413	15,389	715
3.15 p. m..	.6	.30	.25	— .05	— .4	.....	.....	.....	289	......	......	......
3.30 p. m..	.6	.30	.25	— .05	— .4	.....	.....	.....	289	......	......	......
3.45 p. m..	.6	.30	.25	— .05	— .4	.....	.....	.....	288	......	......	......
4 p. m	.6	.30	.25	— .05	— .4	.....	.....	.....	289	1,432	15,353	740
Average ..	.6	.30	.25	— .05	— .4	7.2	11.4	.3	287	1,423	15,121	760

Pressure on oil system, 45 pounds.
Draft pressure in fireroom, 1 inch.
Draft pressure in combustion chamber, 0.25 inch.
Total pounds oil burned, 7,114.
Total pounds feed water, 75,603.
Total pounds steam for burners, 3,801.

No. 59.—*Test of oil fuel in a Hohenstein water-tube marine boiler, May 7, 1903.*

[Four hours' duration with 2-inch forced draft, using Oil City burner, under steam.]

Time.	Steam pressure by gauge.	Temperature of feed.	Calorimeter.			Gauge glass.	Temperature.					Steam pressure on burner (Scotch boiler).
			T_1.	T_2.	Q.		Inside.		Air in fireroom.	Steam or air for burner.	Gases at base of stack.	
							Dry.	Wet.				
	Lbs.	° *F.*	° *F.*	° *F.*		*Ins.*	° *F.*	° *F.*	° *F.*	° *F.*	° *F.*	*Lbs.*
11 a. m....	268	114	400	298	0.9810	2	....	....	108	410	......	90
11.15 a. m.	270	130	400	300	.9820	1	....	....	110	404	......	90
11.30 a. m.	270	120	400	300	.9820	1	99	75	110	402	940	90
11.45 a. m.	272	120	400	298	.9910	2	....	....	110	400	......	90
12 m......	270	120	400	300	.9820	2.75	....	....	112	400	......	90
12.15 p. m.	275	120	400	298	.9810	2	....	....	112	402	......	90
12.30 p. m.	265	120	400	298	.9810	2	100	72	112	404	910	90
12.45 p. m.	270	122	400	300	.9820	1.75	....	....	112	390	......	90
1 p. m	270	122	400	298	.9810	3	....	....	112	380	......	90
1.15 p. m..	265	120	400	298	.9810	1.75	....	....	110	378	......	90
1.30 p. m..	265	118	400	298	.9810	2.25	104	72	112	386	930	90
1.45 p. m..	265	120	400	298	.9810	1	....	....	112	392	......	90
2 p. m	270	120	400	298	.9810	2.25	....	....	112	400	......	90
2.15 p. m..	270	120	400	298	.9810	2	....	....	112	400	......	90
2.30 p. m..	268	118	400	298	.9810	2	102	72	112	394	940	90
2.45 p. m..	270	118	400	298	.9810	1.75	....	....	114	396	......	90
3 p. m	265	116	400	298	.9810	2.75	....	....	114	400	......	90
Average ..	269	119	.....	.....	.9814	.....	101	73	111	396	930	90

Weather, clear.

Barometer at noon, 30 inches.

Test started at 11 a. m.; lighted fires 7 a. m.; 275 pounds of steam at 7.55 a. m.; 2-inch forced draft at 10 a. m.

Six Oil City Boiler Works steam burners of $\frac{3}{16}$-inch opening.

Air openings into furnace, 3 □ and 6 ⊙ (11 to 12), 3 □ and 150 square inches (12 to 1.30), 3 □ and 6 ⊙ (1.30 to 3).

No. 59.—*Test of oil fuel in a Hohenstein water-tube marine boiler, May 7, 1903.*

[Four hours' duration with 2-inch forced draft, using Oil City burner, under steam.]

Time.	Pressure on oil system.	Draft pressure.						Smoke.	Revolutions of fan.	Oil burned per hour.	Feed water per hour.	Steam for burners (feed water, special boiler) per hour.
		Furnace.	Combustion chamber.	Tube chamber.		Above tubes, below drums.	Base of stack.					
				Front.	Back.							
	Lbs.									*Lbs.*	*Lbs.*	*Lbs.*
11 a. m....	45	0.17	0.9	1	0.9	0.25	—0.4	....	386	......	......	......
11.15 a. m.	45	.17	.9	1	.9	.25	— .4	....	395	......	......	......
11.30 a. m.	45	.17	.9	1	.9	.25	-- .45	1½	392	......	......	......
11.45 a. m.	45	.17	.9	1	.9	.25	— .45	....	392	......	......	......
12 m......	45	.17	.9	1	.9	.25	— .45	....	388	1,865	19,324	808
12.15 p. m.	45	.16	.8	1	.85	.25	— .45	....	379	......	......	......
12.30 p. m.	45	.16	.8	1	.85	.25	— .45	1½	379	......	......	......
12.45 p. m.	45	.16	.85	1	.85	.25	— .45	....	385	......	......	......
1 p. m	50	.16	.85	1	.85	.25	— .45	....	386	1,712	18,044	800
1.15 p. m..	50	.16	.85	.9	7	.15	— .4	....	380	......	......	......
1.30 p. m..	50	.16	.85	1	.8	.25	— .45	1	386	......	......	......
1.45 p. m..	50	.16	.85	1	.8	.25	— .45	....	388	......	......	......
2 p. m	50	.16	.85	1	.8	.25	— .45	....	388	1,674	16,128	931
2.15 p. m..	70	.16	.85	1	.8	.25	— .45	....	386	......	......	......
2.30 p. m..	70	.16	.85	1	.8	.25	— .45	2	388	......	......	......
2.45 p. m..	70	.16	.85	1	.85	.25	— .45	....	388	......	......	......
3 p. m	70	.16	.85	1	.8	.25	— .45	....	388	1,921	21,795	1,146
Average ..	52	.163	.86	1	.84	.24	— .44	1½	387	1,793	18,823	921

Temperature of oil in weight tank, 160° F.
Draft pressure in fireroom, 2 inches.
Total pounds oil burned, 7,172.
Total pounds feed water, 75,291.
Total pounds steam for burners, 3,685.

No. 60.—*Test of oil fuel in a Hohenstein water-tube marine boiler, May 8, 1903.*

[Three hours' duration with 3-inch forced draft, using Oil City burner, under steam.]

Time.	Steam pressure by gauge.	Temperature of feed.	Calorimeter.			Gauge glass.	Temperature.					Steam pressure on burner (Scotch boiler).
			T_1.	T_2.	Q.		Inside.		Air in fireroom.	Steam or air for burner.	Gases at base of stack.	
							Dry.	Wet.				
	Lbs.	° *F.*	° *F.*	° *F.*		*Ins.*	° *F.*	° *F.*	° *F.*	° *F.*	° *F.*	*Lbs.*
11 a. m....	265	112	398	296	0.9805	2.5	.....	.....	110	408	......	90
11.15 a. m.	270	112	398	294	.9795	1	.....	.....	110	408	......	90
11.30 a. m.	263	114	398	294	.9795	1	90	69	110	408	1,070	90
11.45 a. m.	270	116	398	296	.9805	1	.....	.....	112	408	......	90
12 m......	272	120	398	294	.9795	3	.....	.....	112	410	......	90
12.15 p. m.	274	118	398	294	.9795	2.5	.....	.....	112	406	......	90
12.30 p. m.	265	116	398	292	.9780	1.5	93	69	112	424	1,030	90
12.45 p. m.	270	116	398	294	.9795	2.5	.....	.....	114	414	......	90
1 p. m	270	120	398	294	.9795	2.5	.....	.....	114	414	......	90
1.15 p. m..	268	112	398	294	.9795	2.5	.....	.....	114	414	......	90
1.30 p. m..	272	112	398	294	.9795	2	93	68	114	416	1,060	90
1.45 p. m..	270	116	398	294	.9795	2.5	.....	.....	114	406	......	90
2 p. m	268	118	398	294	.9795	2.5	.....	.....	114	404	......	90
Average ..	269	116	.....	.....	.9796	.....	92	69	112	411	1,053	90

Barometer at noon, 30.17 inches.
Lighted fires, 7 a. m.; 275 pounds steam 8.05 a. m.; 3-inch forced draft; test started, 11 a. m.
Weather, clear.
Air into furnace, 3 □ + 6 ⊙.
Temperature of oil in weigh tank, 160° F.

No. 60.—*Test of oil fuel in a Hohenstein water-tube marine boiler, May 8, 1903.*

[Three hours' duration with 3-inch forced draft, using Oil City burner, under steam.]

Time.	Pressure on oil system.	Draft pressure.						Smoke.	Revolutions of blower.	Oil burned per hour.	Feed water per hour.	Steam for burners (feed water, special boiler) per hour.
		Furnace.	Combustion chamber.	Tube chamber.		Above tubes, below drums.	Base of stack.					
				Front.	Back.							
	Lbs.									*Lbs.*	*Lbs.*	*Lbs.*
11 a. m....	70	2.4	1.4	1.4	1.3	0.5	−0.5	.....	461	......	....	......
11.15 a. m.	73	2.5	1.4	1.5	1.3	.5	− .4	.....	458	......	....	......
11.30 a. m.	70	2.5	1.4	1.5	1.4	.5	− .4	1½	457	......	....	......
11.45 a. m.	70	2.5	1.4	1.5	1.4	.5	− .4	.....	456	......	....	......
12 m......	75	2.5	1.4	1.5	1.4	.5	− .4	.....	458	2,432	24,282	909
12.15 p. m.	73	2.5	1.4	1.5	1.4	.5	− .4	.....	458	......	....	......
12.30 p. m.	60	2.5	1.4	1.5	1.4	.5	− .4	2	458	......	....	......
12.45 p. m.	60	2.5	1.4	1.5	1.4	.5	− .4	.....	458	......	....	......
1 p. m	75	2.5	1.4	1.5	1.4	.5	− .4	.....	458	2,470	23,784	970
1.15 p. m..	70	2.5	1.4	1.5	1.4	.5	− .4	.....	459	......	....	......
1.30 p. m..	75	2.5	1.4	1.5	1.4	.5	− .4	2	460	......	....	......
1.45 p. m..	75	2.5	1.4	1.5	1.4	.5	− .4	.....	458	......	....	......
2 p. m	75	2.5	1.4	1.5	1.4	.5	− .4	.....	458	2,457	23,832	990
Average ..	71	2.5	1.4	1.5	1.4	.5	− .4	1.8	458	2,453	23,966	956

Draft pressure in fireroom, 3 inches.
Total pounds oil burned, 7,359.
Total pounds feed water, 71,898.
Total pounds steam for burners, 2,869.

No. 61.—*Test of oil fuel in a Hohenstein water-tube marine boiler, May 22, 1903.*

[Six hours' duration with natural draft, using Oil City burner (Fitton nozzle), under steam.]

Time.	Steam pressure by gauge.	Temperature of feed.	Calorimeter.			Gauge glass.	Temperature.					
			T_1.	T_2.	Q.		Inside.		Air in fireroom.	Oil in weigh tank.	Steam or air for burner.	Gases at base of stack.
							Wet.	Dry.				
	Lbs.	° *F.*	° *F.*	° *F.*		*Ins.*	° *F.*	° *F.*	° *F.*	° *F.*	° *F.*	° *F.*
10 a. m ...	265	124	398	300	0.9828	1.5	....	.....	114	.....	312	......
10.15 a. m.	268	120	398	300	.9828	1.5	....	.....	116	.....	322	......
10.30 a. m.	270	110	398	300	.9828	1.5	82	101	116	160	320	590
10.45 a. m.	270	112	398	300	.9828	1.5	....	.....	110	.....	324	......
11 a. m ...	267	118	398	300	.9828	1.5	....	.....	110	.....	330	......
11.15 a. m.	268	120	404	302	.9815	1.5	....	.....	110	.....	332	......
11.30 a. m.	269	120	404	302	.9815	1.5	83	105	112	160	342	600
11.45 a. m.	268	120	404	302	.9815	1.5	....	.....	112	.....	342	......
12 m......	270	120	404	302	.9815	1.5	....	.....	114	.....	348	......
12.15 p. m.	270	120	404	302	.9815	1.5	....	.....	116	.....	346	......
12.30 p. m.	270	118	404	302	.9815	1.5	83	108	116	160	348	590
12.45 p. m.	268	120	404	302	.9815	1.5	....	.....	114	.....	340	......
1 p. m	270	120	404	302	.9815	1.75	....	.....	116	.....	346	......
1.15 p. m..	270	120	404	302	.9815	1.5	....	.....	118	.....	344	......
1.30 p. m..	270	120	404	302	.9815	1.75	83	113	118	160	342	595
1.45 p. m..	270	120	404	302	.9815	1.5	....	.....	118	.....	344	......
2 p. m	270	120	404	302	.9815	1.75	....	.....	118	.....	342	......
2.15 p. m..	270	122	404	302	.9815	2	....	.....	118	.....	342	......
2.30 p. m..	272	120	404	302	.9815	1.75	86	112	118	160	344	600
2.45 p. m..	270	120	402	300	.9815	1.75	....	.....	118	.....	340	......
3 p. m	270	124	402	302	.9825	1.75	....	.....	120	.....	350	......
3.15 p. m..	268	122	402	302	.9825	1.5	....	.....	120	.....	360	......
3.30 p. m..	269	124	402	302	.9825	1.75	84	112	122	160	370	615
3.45 p. m..	270	120	402	302	.9825	1.75	....	.....	120	.....	376	......
4 p. m	270	120	402	302	.9825	1.75	....	.....	120	.....	374	......
Average ..	269	120	.....	.....	.9824	.....	83	108	116	160	343	598

Barometer, 29.94 inches at noon.
Test start at 10 a. m.; lighted fires at 7.50 a. m.; 275 pounds steam at 8.30 a. m.
Weather, partly cloudy.
Air openings into furnace, 3 □ and 6 ⊙.

No. 61.—*Test of oil fuel in a Hohenstein water-tube marine boiler, May 22, 1903.*

[Six hours' duration with natural draft, using Oil City burner (Fitton nozzle), under steam.]

Time.	Steam pressure on burner (Scotch boiler).	Pressure on oil system.	Draft pressure.						Smoke.	Oil burned per hour.	Feed water per hour.	Steam for burners (feed water, special boiler) per hour.
			Furnace.	Combustion chamber.	Tube chamber.		Above tubes, below drums.	Base of stack.				
					Front.	Back.						
	Lbs.	*Lbs.*								*Lbs.*	*Lbs.*	*Lbs.*
10 a. m ...	62	100	0.9	0.2	0.19	0.21	0.31	—0.42	.....	0	0	0
10.15 a. m.	60	120	.7	.2	.18	.21	.32	— .43	.....	......	......	......
10.30 a. m.	60	110	.6	.2	.17	.2	.31	— .41	2	......	......	......
10.45 a. m.	60	110	.7	.2	.18	.21	.31	— .43	.....	......	......	......
11 a. m ...	60	100	.7	.19	.19	.21	.31	— .42	.....	1,052	12,327	875
11.15 a. m.	60	100	.7	.19	.19	.21	.31	— .42	.....	......	......	......
11.30 a. m.	60	100	.7	.2	·19	.21	.31	— .43	1½	......	......	......
11.45 a. m.	60	100	.7	.2	.19	.21	.31	— .43	.....	......	......	......
12 m......	60	100	.7	.2	.19	.21	.31	— .43	.....	997	11,523	793
12.15 p. m.	60	100	.7	.2	.19	·21	.31	— .43	.....	......	......	......
12.30 p. m.	60	100	.7	.2	.19	.21	.31	— .43	1½	......	......	......
12.45 p. m.	60	100	.7	.2	.19	.21	.31	— .43	.....	......	......	......
1 p. m	60	100	.7	.2	.19	.21	.31	— .43	.....	1,005	11,826	847
1.15 p. m..	60	100	.7	.2	.19	.21	.31	— .43	.....	......	......	......
1.30 p. m..	60	100	.7	.2	.19	.21	.31	— .43	1	......	......	......
1.45 p. m..	60	100	.7	.2	.19	.21	.31	— .43	.....	......	......	......
2 p. m	60	100	.7	.2	.19	.21	.31	— .43	.....	951	11,346	844
2.15 p. m..	60	100	.7	.2	.19	.21	.31	— .43	.....	......	......	......
2.30 p. m..	60	105	.7	.2	.19	.21	.31	— .43	¾	......	......	......
2.45 p. m..	60	105	.7	.2	.19	.21	.31	— .43	.....	......	......	......
3 p. m	60	105	.7	.2	.19	.21	.31	— .43	.....	936	10,794	815
3.15 p. m..	60	105	.7	.2	.19	.21	.31	— .43	.....	......	......	......
3.30 p. m..	60	105	.7	.2	.19	.21	.31	— .43	2	......	......	......
3.45 p. m..	60	105	.7	.2	.19	.21	.31	— .43	.....	......	......	......
4 p. m	60	105	.7	.2	.19	.21	.31	— .43	.....	957	10,969	659
Average ..	60	103	.7	.2	.19	.21	.31	— .43	1.5	983	11,464	805

Total pounds oil burned, 5,898.
Total pounds feed water, 68,785.
Total pounds steam for burners, 4,833.

No. 62.—*Test of oil fuel in a Hohenstein water-tube marine boiler, May 25, 1903.*

[Five hours' duration with 1-inch forced draft, using Oil City burner (Fitton nozzle), under steam.]

Time.	Steam pressure by gauge.	Temperature of feed.	Calorimeter.			Gauge glass.	Temperature.					Steam pressure on burner (Scotch boiler).
							Inside.					
			T_1.	T_2.	Q.		Wet.	Dry.	Air in fire room.	Steam for burner.	Gases at base of stack.	
	Lbs.	° *F.*	° *F.*	° *F.*		*Ins.*	° *F.*	° *F.*	° *F.*	° *F.*	° *F.*	*Lbs.*
10.30 a. m.	265	118	400	302	0.9832	1	.....	.....	99	378	.....	60
10.45 a. m.	265	122	400	300	.9820	1	.....	.....	99	388	.....	60
11 a. m.	267	120	400	300	.9820	1	69	84	99	394	775	60
11.15 a. m.	268	118	400	296	.9797	1.5	.....	.....	99	378	.....	60
11.30 a. m.	270	120	400	296	.9797	1	.....	.....	100	368	.....	60
11.45 a. m.	270	120	400	294	.9785	1	.....	.....	100	360	.....	60
12 m.	264	118	400	294	.9785	1	70	87½	100	368	740	60
12.15 p. m.	270	124	402	294	.9778	1	.....	.....	100	367	.....	60
12.30 p. m.	275	120	400	294	.9785	1	.....	.....	100	372	.....	62
12.45 p. m.	270	122	400	294	.9785	1	.....	.....	102	378	.....	60
1 p. m.	275	120	400	294	.9785	1	72	89	102	380	745	60
1.15 p. m.	274	118	402	294	.9778	1	.....	.....	102	378	.....	60
1.30 p. m.	274	118	402	294	.9778	1	.....	.....	104	376	.....	60
1.45 p. m.	270	120	402	294	.9778	1	.....	.....	104	378	.....	60
2 p. m.	270	122	402	294	.9778	1	72	90	104	380	750	60
2.15 p. m.	275	120	402	294	.9778	1.5	.....	.....	104	370	.....	60
2.30 p. m.	272	122	402	294	.9778	1	.....	.....	104	366	.....	60
2.45 p. m.	270	120	400	294	.9785	2	.....	.....	104	372	.....	60
3 p. m.	268	120	402	294	.9778	2	72	91	104	368	720	60
3.15 p. m.	270	120	402	294	.9778	1.5	.....	.....	104	384	.....	60
3.30 p. m.	275	120	402	294	.9778	1.5	.....	.....	104	380	.....	60
Average	270	120	.....	.....	.9789	.....	71	86	102	375	746	60

Barometer at noon, 30.25 inches.
Test starts at 10.30 a. m.; lighted fires at 7 a. m.; 1-inch forced draft, 9 a. m.
Weather, overcast or misty.
Air openings into furnace, 3 □ and 6 ⊙.
Carbon was deposited on walls in front of two burners.
Temperature of oil in weigh tank, 160° F.

No. 62.—*Test of oil fuel in a Hohenstein water-tube marine boiler, May 25, 1903.*

[Five hours' duration with 1-inch forced draft, using Oil City burner (Fitton nozzle), under steam.]

Time.	Pressure on oil system.	Draft pressure.				Flue gases.			Revolutions of blower.	Oil burned per hour.	Feed water per hour.	Steam for burners (feed water, special boiler) per hour.
		Tube chamber.		Above tubes; below drums.	Base of stack.	CO_2.	O.	CO.				
		Front.	Back.									
	Lbs.					*P. ct.*	*P. ct.*	*P. ct.*		*Lbs.*	*Lbs.*	*Lbs.*
10.30 a. m.	120	0.4	0.3	−0.1	−0.5				285			
10.45 a. m.	120	.4	.3	− .1	− .5				287			
11 a. m.	120	.4	.3	− .1	− .5				287			
11.15 a. m.	120	.4	.3	− .1	− .5				286			
11.30 a. m.	125	.4	.3	− .1	− .5				287	1,610	16,291	815
11.45 a. m.	120	.4	.35	− .1	− .5				287			
12 m.	125	.4	.3	− .1	− .5	6.0	13	0.4	286			
12.15 p. m.	125	.4	.3	− .1	− .5				287			
12.30 p. m.	120	.4	.3	− .1	− .5				287	1,550	16,241	839
12.45 p. m.	120	.4	.3	− .1	− .5				287			
1 p. m.	140	.4	.3	− .1	− .5				286			
1.15 p. m.	130	.4	.3	− .1	− .5				287			
1.30 p. m.	130	.4	.3	− .1	− .5				287	1,707	17,674	916
1.45 p. m.	130	.4	.3	− .1	− .5				287			
2 p. m.	130	.4	.3	− .1	− .5	6.8	12	0	287			
2.15 p. m.	130	.4	.3	− .1	− .5				287			
2.30 p. m.	135	.4	.3	− .1	− .5				287	1,607	17,107	797
2.45 p. m.	135	.4	.3	− .1	− .5				287			
3 p. m.	135	.4	.3	− .1	− .5				287			
3.15 p. m.	140	.4	.3	− .1	− .5				287			
3.30 p. m.	140	.4	.3	− .1	− .5				286	1,661	17,616	952
Average	128	.4	.3	− .1	− .5	6.4	12.5	.2	287	1,627	16,986	864

Draft pressure in fire room, 1 inch.
Draft pressure in furnace, 0.8 inch.
Draft pressure in combustion chamber, 0.3 inch.
Total pounds oil burned, 8,135.
Total pounds feed water, 84,929.
Total pounds steam for burner, 4,319.

No. 63.—*Test of oil fuel in a Hohenstein water-tube marine boiler, May 26, 1903.*

[Five hours' duration with 2-inch forced draft, using Oil City burner (Fitton nozzle), under steam.]

Time.	Steam pressure by gauge.	Temperature of feed.	Calorimeter.			Gauge glass.	Temperature.					Pressure on oil system.
			T_1.	T_2.	Q.		Inside.		Air in fireroom.	Steam for burner.	Gases at base of stack.	
							Wet.	Dry.				
	Lbs.	° *F.*	° *F.*	° *F.*		*Ins.*	° *F.*	° *F.*	° *F.*	° *F.*	° *F.*	*Lbs.*
10 a. m ...	274	120	400	294	0. 9785	1. 25	.....	.....	99	346	.....	135
10.15 a. m.	270	118	398	294	. 9792	1. 5	.....	.....	99	392	.....	130
10.30 a. m.	271	118	400	292	. 9775	2	72	84	99	392	795	140
10.45 a. m.	267	116	398	292	. 9780	1. 75	.....	.....	100	378	.....	150
11 a. m ...	271	116	398	292	. 9780	1. 25	.....	.....	100	380	.....	150
11.15 a. m.	270	118	400	292	. 9775	1	.....	.....	99	378	.....	150
11.30 a. m.	270	116	400	292	. 9775	1. 5	71	87	99	372	785	140
11.45 a. m.	270	120	400	292	. 9775	1	.....	.....	100	366	.....	145
12 m......	268	120	400	292	. 9775	1. 5	.....	.....	100	394	.....	140
12.15 p. m.	272	120	400	292	. 9775	1. 5	.....	.....	100	394	.....	150
12.30 p. m.	274	118	402	294	. 9778	1	73	89	100	376	810	150
12.45 p. m.	273	120	402	294	. 9778	1	.....	.....	100	390	.....	135
1 p. m	275	116	402	294	. 9778	1. 25	.....	.....	102	404	.....	120
1.15 p. m..	273	120	402	294	. 9778	1	.....	.....	102	400	.....	120
1.30 p. m..	274	122	402	294	. 9778	1	72	88	104	400	805	120
1.45 p. m..	275	120	402	294	. 9778	1	.....	.....	104	399	.....	120
2 p. m	275	120	402	294	. 9778	1. 5	.....	.....	102	399	.....	120
2.15 p. m..	275	122	400	294	. 9785	2. 25	.....	.....	102	386	.....	140
2.30 p. m..	273	120	402	292	. 9765	2. 5	72	88	102	346	760	155
2.45 p. m..	275	120	402	294	. 9778	1. 5	.....	.....	102	360	.....	160
3 p. m	275	120	402	294	. 9778	2	.....	.....	102	404	.....	160
Average ..	272	119	.....	.....	. 9778	.....	72	87	101	384	791	139

Barometer at noon, 30.33 inches.

Test starts at 10 a. m.; lighted fires, 7.15 a. m.; 275 pounds of steam, 8.15 a. m.; 2-inch forced draft, 9.15 a. m.

Weather, overcast, drizzle 10 to 11.

Air openings into furnace, 3 □ and 6 ◎.

Temperature of oil in weigh tank, 160° F.

No. 63.—*Test of oil fuel in a Hohenstein water-tube marine boiler, May 26, 1903.*

[Five hours' duration with 2-inch forced draft, using Oil City burner (Fitton nozzle), under steam.]

Time.	Draft pressure.					Flue gases.			Revolutions of fan.	Oil burned per hour.	Feed water per hour.	Steam for burners (feed water, special boiler) per hour.
	Furnace.	Combustion chamber.	Front tube chamber.	Above tubes, below drums.	Base of stack.	CO$_2$.	O.	CO.				
						P. ct.	*P. ct.*	*P. ct.*		*Lbs.*	*Lbs.*	*Lbs.*
10 a. m	0.14	0.8	0.9	0.2	−0.6				387			
10.15 a. m	.15	.8	.9	.2	−.5				386			
10.30 a. m	.16	.9	1	.2	−.5				386			
10.45 a. m	.16	.9	1	.2	−.5				380			
11 a. m	.15	.8	.9	.2	−.5				379	1,976	19,319	809
11.15 a. m	.15	.8	.9	.2	−.5				388			
11.30 a. m	.16	.9	1	.3	−.5	5.8	13	0	388			
11.45 a. m	.16	.9	1	.2	−.5				387			
12 m	.16	.9	1	.2	−.5				387	1,955	19,476	750
12.15 p. m	.16	.9	1	.2	−.5				388			
12.30 p. m	.16	.9	1	.2	−.5				388			
12.45 p. m	.16	.9	1	.2	−.5				388			
1 p. m	.15	.9	1	.2	−.5				386	2,060	19,966	777
1.15 p. m	.16	.9	1	.2	−.5				386			
1.30 p. m	.16	.9	1	.2	−.5	7.0	11	0.2	386			
1.45 p. m	.16	.9	1	.2	−.5				385			
2 p. m	.16	.9	1	.2	−.5				386	2,008	20,457	715
2.15 p. m	.16	.9	1	.2	−.5				386			
2.30 p. m	.16	.9	1	.2	−.5				386			
2.45 p. m	.16	.9	1	.2	−.5				387			
3 p. m	.16	.9	1	.2	−.5				386	1,845	18,741	790
Average	.16	.9	1	.2	−.5	6.4	12	0.1	386	1,969	19,592	768

Steam pressure on burners (Scotch boiler), 60 pounds.
Draft pressure in fireroom, 2 inches.
Draft pressure in back chamber, 0.8 inch.
Total pounds oil burned, 9,844.
Total pounds feed water, 97,959.
Total pounds steam for burners, 3,841.

No. 64.—*Test of oil fuel in a Hohenstein water-tube marine boiler, May 28, 1903.*

[Three hours' duration with 3-inch forced draft, using Oil City burner (Fitton nozzle), under steam.]

Time.	Steam pressure by gauge.	Temperature of feed.	Calorimeter.			Gauge glass.	Temperature.					Pressure on oil system.
			T_1.	T_2.	Q.		Inside.		Oil in weigh tank.	Steam or air for burner.	Gases at base of stack.	
							Wet.	Dry.				
	Lbs.	° *F.*	° *F.*	° *F.*		*Ins.*	° *F.*	° *F.*	° *F.*	° *F.*	° *F.*	*Lbs.*
12.45 p. m.	275	120	402	292	0.9765	1	.....	.....	.....	400	.....	125
1 p. m	274	122	400	292	.9775	1.5	.....	.....	.....	388	.....	130
1.15 p. m..	273	118	400	292	.9775	1	86	102	160	380	800	140
1.30 p. m..	274	120	400	292	.9775	1	.....	.....	.....	380	.....	135
1.45 p. m..	275	120	400	292	.9775	1	.....	.....	.....	386	.....	130
2 p. m	275	122	402	292	.9765	1	.....	.....	.....	410	.....	140
2.15 p. m..	273	120	402	292	.9765	1.75	85	103	160	426	845	140
2.30 p. m..	274	120	400	290	.9762	1	.....	.....	.....	408	.....	140
2.45 p. m..	274	118	400	290	.9762	1	.....	.....	.....	416	.....	135
3 p. m	274	120	400	290	.9762	2	.....	.....	.....	396	.....	160
3.15 p. m..	270	118	400	290	.9762	1	85	100	160	406	830	155
3.30 p. m..	273	116	400	292	.9775	1	.....	.....	.....	400	.....	160
3.45 p. m..	272	118	400	292	.9775	1	.....	.....	.....	404	.....	155
Average ..	274	119	.....	.....	.9770	......	85	102	160	400	827	142

Barometer at noon, 30.09 inches.

Test starts at 12.45 p. m.; lighted fires, 8.15 a. m.; 275 pounds steam at 9 a. m.; 3-inch forced draft, 10.15 a. m.

Weather, partly cloudy.

Air openings into furnace, 3 □ and 6 ⊙.

No. 64.—*Test of oil fuel in a Hohenstein water-tube marine boiler, May 28, 1903.*

[Three hours' duration with 3-inch forced draft, using Oil City burner (Fitton nozzle), under steam.]

Time.	Draft pressure.							Smoke.	Revolutions of fan.	Oil burned per hour.	Feed water per hour.	Steam for burners (feed water, special boiler) per hour.
	Fireroom.	Furnace.	Combustion chamber.	Tube chamber.		Above tubes, below drums.	Base of stack.					
				Front.	Back.							
										Lbs.	*Lbs.*	*Lbs.*
12.45 p. m.	3	2.5	1.4	1.6	1.5	0.5	—0.6	.....	473	......	....	......
1 p. m	3	2.5	1.4	1.6	1.5	.5	— .6	.....	472	......	....	......
1.15 p. m..	3	2.5	1.4	1.6	1.5	.5	— .6	1	474	......	....	......
1.30 p. m..	3	2.5	1.4	1.4	1.5	.5	— .6	.....	473	......	....	......
1.45 p. m..	3	2.5	1.4	1.4	1.5	.5	— .6	.....	473	2,159	21,216	929
2 p. m	3	2.5	1.4	1.5	1.4	.5	— .6	.....	477	......	....	......
2.15 p. m..	3	2.5	1.4	1.5	1.4	.5	— .6	1.5	478	......	....	......
2.30 p. m..	3	2.5	1.4	1.5	1.4	.5	— .6	.....	476	......	....	......
2.45 p. m..	3	2.5	1.4	1.5	1.4	.5	— .6	.....	475	2,517	24,761	978
3 p. m	3	2.5	1.4	1.5	1.4	.5	— .6	.....	474	......	....	......
3.15 p. m..	3	2.5	1.4	1.5	1.4	.5	— .6	1.5	475	......	....	......
3.30 p. m..	3	2.5	1.4	1.5	1.4	.5	— .6	.....	472	......	....	......
3.45 p. m..	3	2.5	1.4	1.5	1.4	.5	— .6	.....	472	2,496	25,284	1,002
Average ..	3	2.5	1.4	1.5	1.43	.5	— .6	1.3	474	2,391	23,754	969

Deposit of carbon on wall and on lower tubes near burners.
Steam pressure on burners (Scotch boiler), 60 pounds.
Total pounds oil burned, 7,172.
Total pounds feed water, 71,261.
Total pounds steam for burners, 2,909.

No. 65.—*Test of oil fuel in a Hohenstein water-tube marine boiler, June 2, 1903.*

[Four hours' duration with 2-inch forced draft, using Oil City burner (Fitton nozzle), under steam.]

Time.	Steam pressure by gauge.	Temperature of feed.	Calorimeter.			Gauge glass.	Temperature.					Pressure on oil system.
			T_1.	T_2.	Q.		Inside.		Oil in weigh tank.	Steam for burner.	Gases at base of stack.	
							Wet.	Dry.				
	Lbs.	° *F.*	° *F.*	° *F.*		*Ins.*	° *F.*	° *F.*	° *F.*	° *F.*	° *F.*	*Lbs.*
12 m......	273	124	400	290	0.9762	1.25	.....	.....	.....	310	.....	120
12.15 p. m.	265	120	400	290	.9762	1.25	.....	.....	.....	306	.....	120
12.30 p. m.	275	122	400	292	.9775	1.25	74	95	160	304	630	140
12.45 p. m.	273	120	400	292	.9775	1.25	.....	.....	.....	376	.....	135
1 p. m....	270	118	400	292	.9775	1.25	.....	.....	.....	438	.....	135
1.15 p. m..	275	120	400	292	.9775	1	.....	.....	.....	410	.....	135
1.30 p. m..	260	118	402	294	.9778	1	76	96	160	418	720	150
1.45 p. m..	275	124	402	294	.9778	2	.....	.....	.....	406	.....	155
2 p. m....	275	120	402	298	.9800	1.25	.....	.....	.....	418	.....	160
2.15 p. m..	275	120	402	298	.9800	1	.....	.....	.....	428	.....	155
2.30 p. m..	275	118	400	300	.9820	2.25	77	97	160	412	790	160
2.45 p. m..	274	120	402	300	.9815	2.75	.....	.....	.....	408	.....	155
3 p. m....	275	120	402	300	.9815	1.25	.....	.....	.....	398	.....	160
3.15 p. m..	270	120	402	300	.9815	1	.....	.....	.....	404	.....	160
3.30 p. m..	270	122	402	300	.9815	1	77	98	160	374	770	160
3.45 p. m..	282	120	402	300	.9815	1.25	.....	.....	.....	378	.....	155
4 p. m....	273	118	402	300	.9815	1.25	.....	.....	.....	396	.....	155
Average ..	272	120	.....	.....	.9795	.....	76	96	160	387	727	148

Barometer at noon, 30.29 inches.

Test started at 12 m.; lighted fires at 7 a. m.; 275 pounds steam at 8.05 a. m.; 2-inch forced draft at 10.30 a. m.

Weather, clear.

Air openings into furnace, 3 □ and 6 ●.

No. 65.—*Test of oil fuel in a Hohenstein water-tube marine boiler, June 2, 1903.*

[Four hours' duration with 2-inch forced draft, using Oil City burner (Fitton nozzle), under steam.]

Time.	Draft pressure.							Smoke.	Revolutions of fan.	Oil burned per hour.	Feed water per hour.	Steam for burners (feed water, special boiler) per hour.
	Fireroom.	Furnace.	Combustion chamber.	Tube chamber.		Above tubes, below drums.	Base of stack.					
				Front.	Back.							
										Lbs.	*Lbs.*	*Lbs.*
12 m......	2	1.9	1.3	1.3	1.2	0.4	—0.4	.....	410	......	....	......
12.15 p. m.	2	1.8	1.3	1.3	1.2	.4	— .4	.....	408	......	....	......
12.30 p. m.	2	1.9	1.3	1.3	1.2	.4	— .4	1½	410	......	....	......
12.45 p. m.	2	1.8	1.1	1.2	1.2	.4	— .45	.....	410	......	....	......
1 p. m....	2	1.8	1.1	1.2	1	.3	— .5	.....	410	1,850	18,524	525
1.15 p. m..	2	1.8	1.1	1.2	1	.3	— .5	.....	410	......	....	......
1.30 p. m..	2	1.8	1.1	1.2	1	.3	— .5	2	410	......	....	......
1.45 p. m..	2	1.8	1.1	1.2	1	.3	— .5	.....	410	......	....	......
2 p. m....	2	1.8	1.1	1.2	1	.3	— .5	.....	408	1,850	17,879	495
2.15 p. m..	2	1.8	1.1	1.2	1	.3	— .5	.....	408	......	....	......
2.30 p. m..	2	1.8	1.1	1.2	1	.3	— .5	2	408	......	....	......
2.45 p. m..	2	1.8	1.1	1.2	1	.3	— .5	.....	410	......	....	......
3 p. m....	2	1.8	1.1	1.2	1	.3	— .5	.....	410	1,990	19,460	525
3.15 p. m..	2	1.8	1.1	1.2	1	.3	— .5	.....	406	......	....	......
3.30 p. m..	2	1.8	1.1	1.2	1	.3	— .5	2½	408	......	....	......
3.45 p. m..	2	1.8	1.0	1.2	1	.3	— .5	.....	408	......	....	......
4 p. m....	2	1.8	1.1	1.2	1	.3	— .5	.....	410	2,057	20,758	595
Average ..	2	1.8	1.1	1.22	1.05	.32	— .48	2	409	1,937	19,155	535

Feed water very muddy, due to recent heavy rains.
Steam pressure on burners (Scotch boiler), 40 pounds.
Total pounds oil burned, 7,747.
Total pounds feed water, 76,621.
Total pounds steam for burners, 2,140.

No. 66.—*Test of oil fuel in a Hohenstein water-tube marine boiler, June 3, 1903.*

[Three hours duration with 3-inch forced draft, using Oil City burner (Fitton nozzle), under steam, 90 pounds.]

Time.	Steam pressure by gauge.	Temperature of feed.	Calorimeter.			Gauge glass.	Temperature.					Pressure on oil system.
							Inside.					
			T_1.	T_2.	Q.		Wet.	Dry.	Oil in weigh tank.	Steam for burner.	Gases at base of stack.	
	Lbs.	° *F.*	° *F.*	° *F.*		*Ins.*	° *F.*	° *F.*	° *F.*	° *F.*	° *F.*	*Lbs.*
12.15 p. m.	270	116	402	292	0.9765	1.5	.....	.....	120	430	.....	140
12.30 p. m.	265	126	400	296	.9800	1	.....	.....	.....	420	.....	135
12.45 p. m.	269	120	400	296	.9800	1	78	99	120	430	895	135
1 p. m....	267	116	400	296	.9800	1	.....	.....	.....	438	.....	140
1.15 p. m..	270	122	400	296	.9800	1	.....	.....	.....	444	.....	140
1.30 p. m..	270	124	400	296	.9800	1	.....	.....	.....	428	.....	140
1.45 p. m..	272	120	400	296	.9800	1	80	101	120	438	880	140
2 p. m....	265	116	398	296	.9805	1	.....	.....	.....	436	.....	120
2.15 p. m..	270	116	400	298	.9810	1.5	.....	.....	.....	448	.....	120
2.30 p. m..	268	118	400	298	.9810	1.75	.....	.....	.....	440	.....	120
2.45 p. m..	272	120	400	298	.9810	1.75	80	100	120	438	910	120
3 p. m....	272	120	400	298	.9810	1.75	.....	.....	.....	438	.....	130
3.15 p. m..	270	120	400	298	.9810	2	.....	.....	120	436	.....	130
Average ..	269	120	.....	.....	.9802	......	79	100	120	436	895	131

Barometer at noon, 30.23 inches.

Test starts, 12.15 p. m.; lighted fires, 8 a. m.; 275 pounds steam 8.50 a. m.; 3-inch forced draft, 10.45 a. m.

Weather, clear.

Air openings into furnace, 3 □ and 6 ●.

This run is intended to develop the capacity of the burner; therefore no attempt is made to minimize the amount of steam used for spraying.

No. 66.—*Test of oil fuel in a Hohenstein water-tube marine boiler, June 3, 1903.*

[Three hours duration with 3-inch forced draft, using Oil City burner (Fitton nozzle), under steam, 90 pounds.]

Time.	Draft pressure.							Smoke.	Revolutions of fan.	Oil burned per hour.	Feed water per hour.	Steam for burners (feed water, special boiler), per hour.
				Tube chamber.								
	Fireroom.	Furnace.	Combustion chamber.	Front.	Back.	Above tubes, below drums.	Base of stack.					
										Lbs.	*Lbs.*	*Lbs.*
12.15 p. m.	3	2.5	1.3	1	1.2	0.5	—0.5	.....	460	......	....	......
12.30 p. m.	3	2.6	1.4	1.5	1.3	.5	— .6	.....	457	......	....	......
12.45 p. m.	3	2.6	1.4	1.5	1.3	.5	— .6	1½	460	......	....	......
1 p. m	3	2.6	1.5	1.6	1.4	.5	— .6	.....	462	......	....	......
1.15 p. m..	3	2.6	1.5	1.6	1.4	.5	— .6	.....	465	2,601	25,953	1,321
1.30 p. m..	3	2.5	1.4	1.5	1.3	.5	— .6	.....	459	......	....	......
1.45 p. m..	3	2.5	1.4	1.5	1.3	.5	— .6	1½	460	......	....	......
2 p. m	3	2.5	1.4	1.5	1.3	.5	— .6	.....	460	......	....	......
2.15 p. m..	3	2.5	1.4	1.5	1.3	.5	— .6	.....	458	2,567	25,248	1,386
2.30 p. m..	3	2.5	1.4	1.5	1.3	.5	— .6	.....	460	......	....	......
2.45 p. m..	3	2.5	1.4	1.5	1.3	.5	— .6	2½	459	......	....	......
3 p. m	3	2.5	1.4	1.5	1.3	.5	— .6	.....	463	......	....	......
3.15 p. m..	3	2.5	1.4	1.5	1.3	.5	— .6	.....	462	2,650	26,140	1,468
Average ..	3	2.53	1.4	1.5	1.3	.5	— .6	1.8	460	2,606	25,780	1,392

Steam pressure on burners (Scotch boiler), 90 pounds.
Total pounds oil burned, 7,818.
Total pounds feed water, 77,341.
Total pounds steam for burners, 4,175.

No. 67.—*Test of oil fuel in a Hohenstein water-tube marine boiler, June 11, 1903.*

[Six hours' duration with natural draft, California oil, using Advance burner, under steam.]

Time.	Steam pressure by gauge.	Temperature of feed.	Gauge glass.	Temperature.				Steam pressure on burners (Scotch boiler).	Pressure on oil system.	Draft pressure.	
				Inside.		Oil in weigh tank.	Gases at base of stack.			Furnace.	Combustion chamber.
				Wet.	Dry.						
	Lbs.	° *F.*	*Ins.*	° *F.*	° *F.*	° *F.*	° *F.*	*Lbs.*	*Lbs.*		
10 a. m....	270	116	2	......	......	140	......	45	130	0.06	0.17
10.15 a. m.	270	122	......	......	......	......	......	45	145	.06	.16
10.30 a. m.	272	120	......	86½	108	......	805	45	135	.06	.16
10.45 a. m.	273	120	......	......	......	......	......	45	145	.06	.16
11 a. m....	270	120	......	......	......	140	......	45	140	.06	.17
11.15 a. m.	270	120	......	......	......	......	......	45	155	.06	.17
11.30 a. m.	272	120	......	82	103	......	770	45	140	.06	.17
11.45 a. m.	268	120	......	......	......	......	......	45	165	.06	.17
12 m......	264	122	......	......	......	140	......	45	165	.06	.17
12.15 p. m.	270	124	......	......	......	......	......	45	160	.06	.17
12.30 p. m.	272	122	......	89½	113	......	770	45	160	.06	.17
12.45 p. m.	270	118	......	......	......	......	......	45	160	.06	.17
1 p. m....	270	118	......	......	......	140	......	45	150	.06	.17
1.15 p. m..	270	120	......	......	......	......	......	45	150	.06	.17
1.30 p. m..	270	120	......	87½	113	......	760	45	140	.06	.17
1.45 p. m..	270	120	......	......	......	......	......	45	140	.06	.17
2 p. m....	270	120	......	......	......	140	......	45	140	.06	.17
2.15 p. m..	270	120	......	......	......	......	......	45	140	.06	.17
2.30 p. m..	268	120	......	89	108	......	760	45	140	.06	.17
2.45 p. m..	270	124	......	......	......	......	......	45	140	.06	.17
3 p. m.....	264	120	......	......	......	140	......	45	140	.06	.17
3.15 p. m..	265	120	......	......	......	......	......	45	140	.06	.17
3.30 p. m..	273	124	......	90	114	......	780	45	140	.06	.17
3.45 p. m..	270	124	......	......	......	......	......	45	140	.06	.17
4 p. m....	268	120	2	......	......	140	......	45	140	.06	.17
Average...	270	121	......	87	110	140	774	45	146	.06	.17

Barometer at noon, 29.92 inches.
Start of test, 10 a. m.; started fires at 7.50 a. m.; 275 pounds steam at 8.20 a. m.
Weather overcast.
Air openings into furnace, 8 □ and 4 ⊙ and 40 square inches.

The furnace for this and succeeding tests is in its original condition, the bridge wall and false bottom having been removed.

During preliminary tests it was found necessary to enlarge the holes in the oil nipples from $\frac{1}{32}$ inch to $\frac{1}{16}$ inch. It is probable that with Texas oil and its greater fluidity the small openings would have sufficed.

No. 67.—*Test of oil fuel in a Hohenstein water-tube marine boiler, June 11, 1903.*

[Six hours' duration with natural draft, California oil, using Advance burner, under steam.]

Time.	Draft pressure.				Flue gases.			Smoke.	Oil burned per hour.	Feed water per hour.	Steam for burners (feed water, special boiler) per hour.
	Tube chamber.		Above tubes, below drums.	Base of stack.	CO$_2$.	O.	CO.				
	Front.	Back.									
					P. ct.	*P. ct.*	*P. ct.*		*Lbs.*	*Lbs.*	*Lbs.*
10 a. m.	0.16	0.2	0.35	0.52							
10.15 a. m.	.16	.2	.35	.52							
10.30 a. m.	.16	.2	.35	.53				1½			
10.45 a. m.	.16	.2	.35	.53							
11 a. m.	.16	.2	.35	.53					1,264	13,216	532
11.15 a. m.	.16	.2	.35	.53							
11.30 a. m.	.16	.2	.35	.53	8.4	9.8	0	1½			
11.45 a. m.	.16	.2	.35	.53							
12 m.	.16	.2	.35	.53					1,180	12,604	568
12.15 p. m.	.16	.2	.35	.53							
12.30 p. m.	.16	.2	.35	.53				1½			
12.45 p. m.	.16	.2	.35	.53							
1 p. m.	.16	.2	.35	.53					1,074	11,220	515
1.15 p. m.	.16	.2	.35	.53							
1.30 p. m.	.16	.2	.35	.53	8	10.2	0.4	2			
1.45 p. m.	.16	.2	.35	.53							
2 p. m.	.16	.2	.35	.53					1,228	12,443	490
2.15 p. m.	.16	.2	.35	.53							
2.30 p. m.	.16	.2	.35	.53				2			
2.45 p. m.	.16	.2	.35	.53							
3 p. m.	.16	.2	.35	.53					1,098	11,513	470
3.15 p. m.	.16	.2	.35	.53							
3.30 p. m.	.16	.2	.35	.53				2			
3.45 p. m.	.16	.2	.35	.53							
4 p. m.	.16	.2	.35	.53					1,078	11,307	510
Average	.16	.2	.35	.53	8.2	10	.2	1.7	1,154	12,050	514

Preliminary tests at pressures ranging from 30 to 90 pounds determined 40 pounds to be the most suitable pressure for the spraying agent.

Total pounds oil burned, 6,922.

Total pounds feed water, 72,303.

Total pounds steam for burners, 3,085.

No. 68.—*Test of oil fuel in a Hohenstein water-tube marine boiler, June 12, 1903.*

[Three hours' duration with 3-inch forced draft, using Advance burner, under steam.]

Time.	Steam pressure by gauge.	Temperature of feed.	Calorimeter.			Gauge glass.	Temperature.					Pressure on oil system.
			T_1.	T_2.	Q.		Inside.		Air in fireroom.	Steam for burner.	Gases at base of stack.	
							Wet.	Dry.				
	Lbs.	° *F.*	° *F.*	° *F.*		*Ins.*	° *F.*	° *F.*	° *F.*	° *F.*	° *F.*	*Lbs.*
12.30 p. m.	275	122	398	290	0.9770	1.75	.....	.....	108	443	.....	135
12.45 p. m.	265	124	400	299	.9815	1	.....	.....	109	444	.....	135
1 p. m	270	122	399	290	.9768	.75	75	94	111	488	905	135
1.15 p. m..	265	120	399	289	.9760	.75	.....	.....	111	478	.....	140
1.30 p. m..	270	118	399	289	.9760	1.75	.....	.....	112	495	.....	135
1.45 p. m..	275	118	399	290	.9768	1.75	.....	.....	110	485	.....	120
2 p. m	265	124	399	290	.9768	1.75	75	96	111	490	960	120
2.15 p. m..	272	120	399	290	.9768	1.75	.....	.....	111	494	.....	120
2.30 p. m..	275	122	399	290	.9768	1.75	.....	.....	111	494	.....	130
2.45 p. m..	270	118	399	290	.9768	1	.....	.....	111	495	.....	130
3 p. m	273	118	400	290	.9762	1	74	95	111	497	965	130
3.15 p. m..	270	120	399	289	.9760	1.25	.....	.....	110	502	.....	115
3.30 p. m..	270	120	399	289	.9760	1.75	.....	.....	110	478	.....	120
Average ..	270	120	.....	.....	.9770	.....	75	95	110	483	943	128

Barometer at noon, 29.7 inches.

Test starts at 12.30 p. m.; lighted fires, 9.15 a. m.; 275 pounds steam, 10.15 a. m.; 3-inch forced draft, 11.15 a. m.

Weather, partly cloudy.

Air openings into furnace, 3 □ and 90 square inches.

California oil was used, but it is possible that this oil was slightly mixed with Texas oil, owing to practical difficulty in clearing tank from the residue of Texas oil when such oil was last used

No. 68.—*Test of oil fuel in a Hohenstein water-tube marine boiler, June 12, 1903.*

[Three hours' duration with 3-inch forced draft, using Advance burner, under steam.]

Time.	Draft pressure.							Smoke.	Revolutions of fan.	Oil burned per hour.	Feed water per hour.	Steam for burners (feed water, special boiler) per hour.
	Fireroom.	Furnace.	Cumbustion chamber.	Tube chamber.		Above tubes below drums.	Base of stack.					
				Front.	Back.							
										Lbs.	*Lbs.*	*Lbs.*
12.30 p. m.	3	2.6	1.9	1.8	1.7	0.7	—0.5	.....	472	......	....	......
12.45 p. m.	3	2.6	2	1.8	1.7	.7	— .5	.....	475	......	....	......
1 p. m	3	2.6	2	1.8	1.7	.7	— .5	1.5	474	......	....	......
1.15 p. m..	3	2.6	2	1.8	1.7	.7	— .5	.....	471	......	....	......
1.30 p. m..	3	2.6	2	1.8	1.7	.7	— .5	.....	472	2,609	23,478	619
1.45 p. m..	3	2.6	2	1.8	1.7	.7	— .5	.....	470	......	....	......
2 p. m	3	2.6	2	1.8	1.7	.7	— .5	2	471	......	....	......
2.15 p. m..	3	2.6	2	1.8	1.7	.7	— .5	.....	472	......	....	......
2.30 p. m..	3	2.6	2	1.8	1.7	.7	— .5	.....	472	2,614	23,984	686
2.45 p. m..	3	2.6	2	1.8	1.7	.7	— .5	.....	470	......	....	......
3 p. m	3	2.6	2	1.8	1.7	.7	— .5	2	472	......	....	......
3.15 p. m..	3	2.6	2	1.8	1.7	.7	— .5	.....	472	......	....	......
3.30 p. m..	3	2.6	2	1.8	1.7	.7	— .5	.....	474	2,722	25,318	690
Average ..	3	2.6	2	1.8	1.7	.7	— .5	1.8	472	2,648	24,260	665

Temperature of oil in weigh tank, 130° F.
Steam pressure on burner (Scotch boiler), 45 pounds.
Total pounds oil burned, 7,945.
Total pounds feed water, 72,780.
Total pounds steam for burners, 1,995.

No. 69.—*Test of oil fuel in a Hohenstein water-tube marine boiler, June 16, 1903.*

[Four hours' duration with natural draft, using Oil City burner (Fitton nozzle), under air.]

Time.	Steam pressure by gauge.	Temperature of feed.	Calorimeter.			Gauge glass.	Temperature.					
			T_1.	T_2.	Q.		Inside.		Air in fireroom.	Oil in weigh tank.	Air for burner.	Gases at base of stack.
							Wet.	Dry.				
	Lbs.	°*F.*	°*F.*	°*F.*		*Ins.*	°*F.*	°*F.*	°*F.*	°*F.*	°*F.*	°*F.*
11.45 a. m.	270	120	400	296	0.9798	2	81	106	112	134	340	670
12 m......	270	120	400	296	.9798	2	.....	......	110	150	338	.....
12.15 p. m.	271	124	400	296	.9798	1.25	.....	.....	111	.....	338	.....
12.30 p. m.	270	120	400	295	.9790	1.5	83	109	110	150	338	685
12.45 p. m.	267	120	400	296	.9798	1.5	.....	......	111	.....	337	.....
1 p. m....	271	120	400	296	.9798	2	.....	......	111	150	338	.....
1.15 p. m..	270	124	399	295	.9795	1.25	.....	......	111	.....	352	.....
1.30 p. m..	270	122	399	295	.9795	1.75	85	109	111	150	348	705
1.45 p. m..	270	120	399	295	.9795	1.75	.....	......	111	.....	320	.....
2 p. m....	265	120	399	295	.9795	2	.....	......	110	150	318	.....
2.15 p. m..	267	118	400	296	.9798	1.75	.....	......	110	.....	350	.....
2.30 p. m..	268	120	399	295	.9795	1.5	81	107	112	150	352	635
2.45 p. m..	268	120	400	296	.9798	1.5	.....	......	112	.....	350	.....
3 p. m....	265	120	399	295	.9795	2	.....	......	109	150	350	.....
3.15 p. m..	270	122	400	296	.9798	1.25	.....	......	110	150	348	.....
3.30 p. m..	268	124	399	295	.9795	1.25	83	108	110	150	345	680
3.45 p. m..	270	120	400	296	.9798	1.25	.....	......	110	160	342	.....
Average ..	269	121	.....	.....	.9796	.....	82.6	107.8	111	150	341	675

Barometer at noon, 29.83 inches.
Test starts at 11 a. m.; started fires at 7 a. m.; 275 pounds steam at 8.05 a. m.
Weather, clear.
Air openings into furnace.

No. 69.—*Test of oil fuel in a Hohenstein water-tube marine boiler, June 16, 1903.*

[Four hours' duration with natural draft, using Oil City burner (Fitton nozzle), under air.]

Time.	Revolutions of air compressor.	Air pressure on burner.	Pressure on oil system.	Draft pressure.						Smoke.	Oil burned per hour.	Feed water per hour.
				Furnace.	Combustion chamber.	Tube chamber.		Above tubes, below drums.	Base of stack.			
						Front.	Back.					
		Lbs.	*Lbs.*								*Lbs.*	*Lbs.*
11.45 a. m.	73	48	120	0.06	0.15	0.15	0.18	0.31	—0.47	1	......	......
12 m......	73	48	128	.06	.15	.15	.18	.31	— .47	.....	......	......
12.15 p. m.	73	48	150	.06	.15	.15	.18	.31	— .47	.....	......	......
12.30 p. m.	74	48	150	.06	.15	.15	.18	.31	— .47	2	......	......
12.45 p. m.	73	48	135	.06	.15	.15	.18	.31	— .47	.....	1,070	11,985
1 p. m	73	48	160	.06	.15	.15	.18	.31	— .47	.....	......	......
1.15 p. m..	84	62	155	.06	.14	.15	.18	.31	— .47	.....	......	......
1.30 p. m..	84	61	155	.06	.14	.15	.18	.31	— .47	2	......	......
1.45 p. m..	96	64	160	.06	.14	.15	.18	.31	— .47	.....	1,070	13,765
2 p. m	101	66	160	.06	.14	.15	.18	.31	— .47	.....	......	......
2.15 p. m..	42	25	140	.06	.15	.15	.18	.31	— .47	.....	......	......
2.30 p. m..	44	25	120	.06	.15	.15	.18	.31	— .47	1½	......	......
2.45 p. m..	46	25	115	.06	.15	.15	.18	.31	— .47	.....	1,254	11,555
3 p. m	48	30	110	.06	.15	.15	.18	.31	— .47	.....	......	......
3.15 p. m..	48	30	115	.06	.15	.15	.18	.31	— .47	.....	......	......
3.30 p. m..	46	30	110	.06	.15	.15	.18	.31	— .47	1½	......	......
3.45 p. m..	46	28	130	.06	.15	.15	.18	.31	— .47	.....	1,044	11,950
Average ..	66	43	136	.06	.15	.15	.18	.31	— .47	1.6	1,109	12,314

California oil used nominally, but in all probability was a composition mainly of Texas oil, as it was the final heavy residue left in the tank. For this test the suction pipe was lowered for purpose of completely draining the tank. Before this test the tank had never been completely drained. A sample of these final drainings or dregs was taken and sent on to the navy-yard for analysis.

Total pounds oil burned, 4,438.

Total pounds feed water, 49,255.

Summary of oil-burning tests with

No. of trial.	Date of trial.	Duration of trial (hours).	Kind of oil.	Oil burner used.	State of weather.
1	2	3	4	5	6
	1902.				
1......	June 11	6	Beaumont oil.........	Oil City Wks. (air) ...	Bright, sunny day........
2......	June 12	4	.....do................	.....do................	.....do..................
3......	June 26	8	.....do................	.....do................	.....do..................
4......	June 27	3	.....do................	.....do................	Bright sun, few clouds....
5......	Aug. 2	5	.....do................	.....do................	Bright, sunny day........
6......	Aug. 4-9	116	.....do................	.....do................	(See log).................
7......	Aug. 15	6	.....do................	.....do................	Thin, fleecy clouds........
8......	Aug. 20	3	.....do................	.....do................	Smoky; occasional clouds.
9......	Sept. 12	6	.....do................	Hayes (steam)........	Partly cloudy............
10......	Sept. 19	8	.....do................	Oil City Wks. (steam).	Thin clouds...............
11......	Sept. 20	8	.....do................	.....do................	.....do..................
12......	Sept. 22	8	.....do................	.....do................	Partly cloudy............
13......	Sept. 27	8	.....do................	Reed (air and steam).	Fair......................
14......	Sept. 29	8	.....do................	.....do................	Clear.....................
15......	Oct. 4	8	.....do................	Oil City (steam)......	Overcast, then drizzling ..
16......	Oct. 13	6	.....do................	.....do................	Clear and pleasant........
17......	Oct. 14	4	.....do................	.....do................	Partly cloudy............
18......	Oct. 22	5	.....do................	.....do................	Clear.....................
19......	Oct. 25	2.5	.....do................	.....do................	.....do..................
20......	Oct. 27	7	.....do................	.....do................	Drizzling and rain........
21......	Nov. 14	7	.....do................	Advance Co. (steam) .	Misty.....................
22......	Nov. 17	8	.....do................	Advance Co. (air)....	Misty and cloudy.........
23......	Nov. 28	8	.....do................	Branch (steam)	Cloudy....................
24......	Dec. 1	4	.....do................	.....do................	Partly cloudy to clear....
25......	Dec. 2	2.75	.....do................	Branch (air)..........	Clear and dry............
26......	Dec. 4	4	.....do................	.....do................	Heavy mist...............
27......	Dec. 5	5	.....do................	Branch (steam)......	Wet and snowing.........
28......	Dec. 6	1.92	.....do................	Branch (air)	Heavy mist, then clearing.
29......	Jan. 1,'03	4	.....do................	Best (steam)..........	Misty.....................
30......	Jan. 3	6	.....do................	.....do................	Overcast; heavy fog.......
31......	Jan. 5	4	.....do................	.....do................	....
32......	Jan. 10	8	.....do................	Harvey system (air)..	Clear, dry, and cold ......
33......	Jan. 12	8	.....do................	.....do................	Clear and cold............
34......	Jan. 15	8	.....do................	Best (air)..............	....
35......	Jan. 16	6	.....do................	.....do................	....
36......	Jan. 17	5	.....do................	.....do................	....
37......	Jan. 19	3	.....do................	.....do................	Cold and clear............
38......	Jan. 20	6	.....do................	Best (steam)..........	....

Hohenstein marine water-tube boiler.

			Average pressure.									
						Draft pressure in inches of water.						
									Tube chamber.			
No. of trial.	Height of barometer at noon.	Degree of humidity.	Steam pressure by gauge; corrected for water level (pounds per square inch).	Pressure of medium used for spraying oil (pounds per square inch).	Pressure on oil (pounds per square inch).	Fireroom.	Furnace.	Combustion chamber.	Front.	Back.	Above tubes and below drums.	Base of stack.
1	7	7.1	8	9	9.1	10	11	12	13	13.1	13.2	14
1....	30.02	......	273.5	3.20	......	1.27	0.78	0.642	0.25	....	....	−0.49
2....	30	......	273.5	4.62	......	2.31	1.55	1.38	.83	....	....	− .05
3....	29.70	......	273.5	.78	......	0	− .15	− .19	− .25	....	....	− .35
4....	29.94	......	273.5	3.37	......	3.25	2.60	2.02	1.25	....	....	− .41
5....	30.18	......	273.5	1.41	......	0	− .15	− .20	− .28	....	....	− .40
6....	29.89	......	271.5	1.31	......	0	− .17	− .23	− .30	....	....	− .46
7....	30.10	......	272.5	4.66	......	0	− .09	− .13	− .21	....	....	− .54
8....	30.08	......	276	4.68	......	3.75	3.40	2.30	1.86	....	....	− .53
9....	30.16	......	273.5	32	......	0	− .20	− .20	− .20	....	....	− .38
10....	30.20	......	273.1	29.9	......	0	− .20	− .20	− .28	....	....	− .60
11....	30.18	......	273.7	61.4	......	0	− .14	− .20	− .28	....	....	− .53
12....	30.05	......	274.2	91	......	0	− .14	− .16	− .21	....	....	− .53
13...	29.92	......	276.7	92	......	0	− .15	− .15	− .20	....	....	− .45
14....	29.96	......	277.4	89	......	0	− .097	− .10	− .20	....	....	− .50
15....	29.99	......	276.6	91.8	45	0	− .14	− .15	− .25	....	....	− .50
16....	29.85	59	275.1	92	45	1.03	1.03	.54	.26	....	....	− .50
17....	29.93	66	273.2	90.2	45	2.04	1.69	1.28	.82	....	....	− .50
18....	30.37	45	275.2	90	45	2.01	1.51	1.23	.65	....	....	− .52
19....	30.14	58	273.2	91	32	3.02	2.61	2.23	1.25	....	....	− .41
20....	29.96	86	274.3	91	31	1	.80	.57	.29	....	....	− .50
21....	30.23	82	271.9	90	35	0	− .133	− .234	− .210	−0.233	−0.383	− .525
22....	30.16	74	272.3	85	25	0	− .128	− .225	− .205	− .232	− .388	− .514
23....	30.14	......	272	91.5	55	0	− .136	− .125	− .196	− .219	− .404	− .556
24....	30.10	......	274	94.2	55	2	1.60	1	1.01	.90	− .22	− .532
25....	29.96	......	264.6	49.1	30	2	1.60	1	1	1	− .30	− .422
26....	30.04	......	274.6	49.2	36.5	2	1.60	1	1.05	.974	− .268	− .42
27....	29.69	......	273.9	90.9	55	2	1.60	1	1	.97	− .26	− .43
28....	30.36	......	273.4	49	35	2	1.60	1	1	.95	− .29	− .38
29....	30.30	......	273.5	90	30	2	1.50	1	1	1	.20	− .40
30....	29.63	......	273.2	90	30	1	.80	.47	.45	.45	− .05	− .50
31....	29.85	......	273.2	90	33	3	2.40	1.60	1.60	1.50	.50	− .30
32....	30.17	......	274.6	23	18	0	.17	.243	.226	.241	.411	.534
33....	30.04	......	274.5	23	16	0	.147	.243	.223	.243	.38	.52
34....	30.03	......	274.1	70	25	0	.138	.238	.217	.236	.398	.54
35....	30.04	......	275.5	71	25	1	.80	.45	.43	.45	− .02	− .55
36....	30.70	......	272.5	70	24	2	1.45	.95	.93	.95	.3	− .50
37....	30.55	......	273.5	70	20	3	2.60	1.62	1.6	1.62	.6	− .60
38....	30.38	......	272.5	90.5	20	0	.117	.28	.26	.28	.44	.614

Summary of oil-burning tests with

No. of trial.	Date of trial.	Duration of trial (hours).	Kind of oil.	Oil burner used.	State of weather.
1	2	3	4	5	6
	1903.				
39	Feb. 6	7	Beaumont oil	Advance (steam)	Clear
40	Feb. 9	8	do	do	Clear cold; breeze NW.
41	Feb. 13	8	do	do	Clear
42	Feb. 27	4	do	do	Overcast; rain 2.30 to 5
43	Mar. 2	6	do	do	Clear and cold
44	Mar. 3	3	do	do	Clear
45	Mar. 14	4	do	Oil City Wks. (steam)	Clear and pleasant
46	Apr. 9	8	do	Santa Fe (steam)	Clear and warm
47	Apr. 10	4	do	do	do
48	Apr. 17	6	California oil	do	Clear
49	Apr. 18	4	do [a]	do	do
50	Apr. 20	3	do	do	Overcast
51	Apr. 21	4	do	do	Clear
52	Apr. 22	2	do	do	do
53	Apr. 23	2	do	do	Partly cloudy
54	Apr. 24	3	do	do	Clear
55	Apr. 27	4	do	MacDonald (steam)	do
56	May 4	4	do	Oil City Wks. (steam)	do
57	May 5	6	do	do	do
58	May 6	5	do	do	do
59	May 7	4	do	do	do
60	May 8	3	do	do	
61	May 22	6	do	do	Partly cloudy
62	May 25	5	do	do	Overcast and misty
63	May 26	5	do	do	Overcast and drizzly
64	May 28	3	do	do	Partly cloudy
65	June 2	4	do	do	Clear
66	June 3	3	do	do	do
67	June 11	6	do	Advance (steam)	Overcast
68	June 12	3	Calif. and Texas oils	do	Partly cloudy
69	June 16	4	do	Oil City (air)	Clear

Hohenstein marine water-tube boiler.

			Average pressure.									
						Draft pressure in inches of water.						
									Tube chamber.			
No. of trial.	Height of barometer at noon.	Degree of humidity.	Steam pressure by gauge; corrected for water level (pounds per square inch).	Pressure of medium used for spraying oil (pounds per square inch).	Pressure on oil (pounds per square inch).	Fireroom.	Furnace.	Combustion chamber.	Front.	Back.	Above tubes and below drums.	Base of stack.
1	7	7.1	8	9	9.1	10	11	12	13	13.1	13.2	14
39....	30.29	......	273.5	60	60	0	0.097	0.224	0.192	0.221	0.382	0.526
40....	30.15	......	273.5	30	40	0	.05	.205	.170	.203	.373	.542
41....	30.03	......	273.5	20	27.6	0	.05	.197	.177	.21	.38	.53
42....	30.26	......	272.5	20	25	2	1.70	1.20	1.20	1.14	.372	− .32
43....	30.47	......	272.5	20	25	1	.80	.45	.42	.45	− .094	− .50
44....	30.55	27	273.5	20	25	3	2.60	1.86	1.85	1.65	.61	− .42
45....	30.20	32	273.5	90	60	3.7	2.92	.83	1.87	1.82	1.90	− .46
46....	29.94	46	269.5	90	9	0	.20	.28	.265	.27	.35	.45
47....	30.09	28	271.5	90	9	1	.60	.20	.28	.20	− .10	− .45
48....	29.77	36	273.5	90	10.6	0	.16	.27	.25	.26	.35	.44
49....	29.79	36	273.5	90	11	1	.65	.25	.20	.20	− .10	− .40
50....	29.66	47	273.5	90	10	3	2.30	1.30	1.40	1.20	.50	− .45
51....	29.70	25	267.5	90	23	3	2	1.20	1.30	1.10	.40	− .45
52....	29.81	30	267.5	90	23	3	1.95	1	1.20	1	.45	− .35
53....	29.90	29	262.5	90	25.4	3	1.95	1.12	1.20	1.10	.40	− .44
54....	30.05	22	265.5	90	75	3	2.20	1.20	1.30	1.17	.48	− .45
55....	30.20	32	263.5	90	40	0	.14	.27	.24	.27	.363	.45
56....	30.20	41	265.5	90	40	0	.15	.27	.25	.27	.36	.46
57....	30.19	36	265.5	90	41	0	.16	.27	.245	.27	.36	.46
58....	30.16	24	267.5	90	45	1	.60	.25	.30	.25	− .05	− .40
59....	30	25	267.5	90	52	2	.163	.86	1	.84	.24	− .44
60....	30.17	30	267.5	90	71	3	2.50	1.40	1.50	1.40	.50	− .40
61....	29.94	38	267.5	60	103	0	.70	.20	.19	.21	.31	− .43
62....	30.25	47	268.5	60	128	1	.80	.30	.40	.30	− .10	− .50
63....	30.33	47	270.5	60	139	2	.16	.90	1	.80	.20	− .50
64....	30.09	50	272.5	60	142	3	2.50	1.40	1.50	1.43	.50	− .60
65....	30.29	39	270.5	40	148	2	1.80	1.10	1.22	1.05	.32	− .48
66....	30.23	39	267.5	90	131	3	2.53	1.40	1.50	1.30	.50	− .60
67....	29.92	40	268.5	45	146	0	.06	.17	.16	.20	.35	.53
68....	29.70	39	268.5	45	128	3	2.60	2	1.80	1.70	.70	− .50
69....	29.83	36	267.5	43	136	0	.06	.15	.15	.18	.31	− .47

Summary of test of Hohenstein marine

No. of trial.	Approximate fireroom air pressure (inches of water).	Revolutions of fan blower per minute.	Draft openings into furnace (aggregate area in square inches).	Average temperatures (° F.).				
				Outside air.		Air in fireroom (5 feet above floor).	Oil in weighing tank.	Medium used in spraying oil.
				Dry bulb.	Wet bulb.			
1	10	15	15.1	16	16.1	17	17.2	18
1......	1.3	327	....	85.4	....	121	....	(?)
2......	2.3	423	....	86	....	121.5	....	(?)
3......	0	0	....	79	....	106	....	102.5
4......	3.3	483	....	81	....	108	....	122
5......	0	0	....	87	....	112	....	120
6......	0	0	....	79	....	112	....	113.5
7......	0	0	....	77.6	....	120	....	161
8......	3.75	506	....	82	....	115	....	136
9......	0	0	....	75	....	98	....	(?)
10......	0	0	....	69	....	98	....	444.4
11......	0	0	....	77	....	106	....	408.2
12......	0	0	....	77	....	103	....	401
13......	0	0	....	80.4	....	99.4	....	375
14......	0	0	....	85.4	....	111.5	....	416
15......	0	0	500	64.4	....	91.2	65.8	407.4
16......	1	303	692	76.3	67.8	114.6	68	482
17......	2	392	830	68.2	61.6	104	65	545
18......	2	380	554	61.3	49.8	97.6	58.6	534
19......	3	463	800	77	67.7	112	65	469
20......	1	287	800	68.1	65.6	108.7	65	420
21......	0	0	569	58.2	55.3	78.3	54	321
22......	0	0	369	57.2	53	81.5	56	243
23......	0	0	476	....	....	72	46	370
24......	2	382	476	....	....	82	42	378
25......	2	392	476	....	....	82.7	46	326
26......	2	384	680	....	....	80	46	333
27......	2	369	660	Air at ash-pit opening.		72	40	379
28......	2	370	672			70.4	31	310
29......	2	383	776	86.4	72	71.5	36	427.4
30......	1	283	776	108.8	81.1	83.6	32	407.1
31......	3	448	776	101.8	78.6	77.5	40	443.5
32......	0	0	776	113.4	85.9	86	30	341.9
33......	0	0	752	90.2	76.8	58.6	25.4	294.4
34......	0	0	....	....	....	73	37	288
35......	1	285	....	....	....	87	36	340

water-tube boiler, burning oil.

	Average temperatures (° F.).			Oil.		Steam.		Water.			
No. of trial.	Chimney gases.	Feed water entering boiler.	Steam at gauge pressure from steam tables (8).	Weight of oil used during test (pounds).	Weight of steam used directly or indirectly in spraying oil, in the latter case assuming 34½ evaporative units per hour per I. H. P.	Quality.	Percentage of moisture in steam, 100−100×(24).	Total weight of water fed to boiler, pounds (corrected for inequality of water level and steam pressure at beginning and end of tests).	Equivalent weight of water evaporated into dry steam (pounds), (26)×(24).	Factor of evaporation (*H*−*h*)+965.7.	Equivalent weight of water evaporated into dry steam from and at 212° F. (pounds), (27)×(28).
1	19	20	21	22	23	24	25	26	27	28	29
1....	704.6	120.7	413.7	10,580	2,820	0.983	1.7	117,976	115,960	1.159	134,400
2....	779	103.2	413.7	9,180	3,770	.980	2	96,928	94,980	1.177	111,800
3....	503.6	123.5	413.7	6,122	827	.984	1.6	78,000	76,740	1.151	88,330
4....	854	119	413.7	8,602	2,550	.981	1.9	88,604	86,915	1.161	100,900
5....	557	129	413.7	4,668	1,153	.986	1.4	58,529	57,700	1.151	66,380
6....	585	119.4	413.1	96,517	18,240	.985	1.5	1,192,482	1,174,500	1.160	1,363,000
7....	747	119.7	413.4	9,089	7,800	.995	.5	104,631	104,100	1.160	120,780
8....	1,017	119	414.5	9,909	3,950	.988	1.2	92,997	91,870	1.161	106,690
9....	449	127	413.7	3,600	2,524	.991	.9	43,761	43,367	1.158	50,000
10....	596	118.3	413.6	7,360	3,412	.995	.5	85,791	85,350	1.162	99,170
11....	628	120.2	413.8	8,257	4,252	.994	.6	96,469	95,880	1.160	111,190
12....	661	119.6	414.0	8,974	5,305	.995	.5	105,547	105,020	1.160	121,840
13....	578	121.9	414.8	7,692	8,166	.996	.4	95,605	95,310	1.158	110,370
14....	645	120.8	415.0	9,216	6,838	.998	.2	112,115	111,890	1.159	129,570
15....	635.6	119.9	414.7	8,071	4,881	.985	1.5	91,869	90,491	1.160	104,970
16....	701	119.3	414.3	9,379	2,204	.971	2.9	95,283	92,520	1.161	107,410
17....	849	119.1	413.6	9,220	1,445	.982	1.8	82,414	80,931	1.161	93,961
18....	842	119.9	414.3	10,585	3,126	.982	1.8	104,785	102,899	1.159	119,260
19....	1,050	109.2	413.6	7,445	2,654	.982	1.8	68,246	67,018	1.171	78,478
20....	818	118.7	414	13,781	8,646	.984	1.6	149,160	146,773	1.161	170,403
21....	640	119.9	413.1	7,517	7,237	.981	1.9	85,069	83,453	1.160	108,405
22....	642	119.5	413.4	8,676	9,524	.984	1.6	100,300	98,695	1.161	114,486
23....	699	119.8	413.8	10,117	9,885	.985	1.5	116,120	114,378	1.160	132,678
24....	796	110.2	414	7,995	4,341	.981	1.9	80,128	78,605	1.170	91,968
25....	778	110.6	411	5,388	3,416	.981	1.9	54,326	53,294	1.169	62,301
26....	740	109.2	414.2	7,240	3,312	.979	2.1	70,765	69,278	1.171	81,124
27....	816	102.1	413.9	10,475	5,939	.979	2.1	103,501	101,327	1.179	119,464
28....	733	102.4	413.8	3,697	2,163	.977	2.3	37,804	36,935	1.178	43,509
29....	750	94.6	413.8	8,159	2,672	.976	2.4	81,697	79,736	1.187	94,647
30....	687.5	106.3	413.7	10,163	4,787	.976	2.4	109,310	106,686	1.174	125,249
31....	790	97.4	413.7	9,940	3,299	.974	2.6	102,242	99,584	1.183	117,808
32....	565	118.1	414.2	7,686	3,174	.984	1.6	92,890	91,408	1.162	106,210
33....	540.2	118	414.2	7,362	3,588	.983	1.7	90,803	89,259	1.162	103,719
34....	....	118.6	414	9,068	9,524	.9837	1.63	106,839	105,097	1.161	122,017
35....	....	107	414.4	10,280	7,659	.9765	2.85	110,952	108,344	1.174	127,196

Summary of test of Hohenstein marine

No. of trial.	Approximate fireroom air pressure (inches of water).	Revolutions of fan blower per minute.	Draft openings into furnace (aggregate area in square inches).	Average temperatures (° F.).				
				Outside air.		Air in fireroom (5 feet above floor).	Oil in weighing tank.	Medium used in spraying oil.
				Dry bulb.	Wet bulb.			
1	10	15	15.1	16	16.1	17	17.2	18
36......	2	375	....	....	....	80	36	358
37......	3	445	....	72	62	59	28	366
38......	0	0	....	....	....	63	29	358
39......	0	0	....	130	98	83	37.5	384
40......	0	0	....	125	95.6	84	37	396
41......	0	0	....	153	110	104	....	401
42......	2	385	....	....	....	90	....	400
43......	1	280	....	120	95	85	....	376
44......	3	458	....	77	57	89	....	423
45......	3.7	501	....	94	71	104	....	447
46......	0	0	....	78	64	88	....	334
47......	1	280	....	88	65	102	....	375
48......	0	0	....	81	63	84	110	334
49......	1	280	....	84	65	98	....	352
50......	3	464	....	84	69	96	....	378
51......	3	460	....	83	61	92	....	364
52......	3	457	....	78	59	87	....	362
53......	3	456	....	76	57	86	....	356
54......	3	457	....	86	62	96	....	374
55......	0	0	....	90	67.6	93	160	325
56......	0	0	....	84	67	88	160	332
57......	0	0	....	87	68	88	160	340
58......	1	287	....	97	70	108	160	375
59......	2	387	....	101	73	111	160	396
60......	3	458	....	92	69	112	160	411
61......	0	0	....	108	83	116	160	343
62......	1	287	....	86	71	102	160	375
63......	2	386	....	87	72	101	160	384
64......	3	474	....	102	85	....	160	400
65......	2	409	....	96	76	....	160	387
66......	3	460	....	100	79	....	120	436
67......	0	0	....	110	87	90	140	....
68......	3	472	....	95	75	110	130	483
69......	0	0	....	108	83	111	150	341

water-tube boiler, burning oil—Continued.

	Average temperatures (° F.).			Oil.		Steam.		Water.			
No. of trial.	Chimney gases.	Feed water entering boiler.	Steam at gauge pressure from steam tables (8).	Weight of oil used during test (pounds).	Weight of steam used directly or indirectly in spraying oil, in the latter case assuming 34½ evaporative units per hour per I. H. P.	Quality.	Percentage of moisture in steam, 100–100×(24).	Total weight of water fed to boiler, pounds (corrected for inequality of water level and steam pressure at beginning and end of tests).	Equivalent weight of water evaporated into dry steam (pounds), (26)×(24).	Factor of evaporation (*H*—*h*)÷965.7.	Equivalent weight of water evaporated into dry steam from and at 212° F. (pounds), (27)×(28).
1	19	20	21	22	23	24	25	26	27	28	29
36....	....	102	413.5	9,824	6,727	0.9757	2.43	101,917	99,440	1.178	117,140
37....	717	97	413.8	6,950	3,726	.9749	2.51	67,620	65,923	1.184	78,053
38....	....	120	413.5	7,216	3,744	.9818	1.82	86,061	84,495	1.159	97,930
39....	610	119	413.8	6,829	3,936	.9850	1.50	74,692	73,572	1.161	85,417
40....	662	120	413.8	9,578	4,207	.9858	1.42	108,212	106,675	1.160	123,748
41....	644	120	413.8	8,741	3,098	.9859	1.41	98,343	96,956	1.160	112,468
42....	714	119	413.5	6,578	1,680	.9756	2.44	61,374	59,876	1.161	69,516
43....	698	120	413.5	8,385	2,683	.9775	2.25	82,486	80,630	1.160	93,530
44....	775	119	413.8	6,005	1,299	.9761	2.39	54,872	53,560	1.161	62,183
45....	819	108	413.8	10,460	3,239	.9762	2.38	108,257	105,680	1.172	123,857
46....	462	119	412.6	5,758	6,793	.9831	1.69	67,548	66,406	1.161	77,097
47....	578	120	413.2	5,245	3,148	.9836	1.64	58,942	57,975	1.160	67,251
48....	487	120	413.8	4,571	5,358	.9807	1.93	51,746	50,747	1.160	58,866
49....	535	119	413.8	5,213	4,016	.9829	1.71	55,281	54,336	1.161	63,084
50....	743	117	413.8	6,021	3,878	.9813	1.87	59,009	57,905	1.163	67,343
51....	722	121	412.2	5,802	3,197	.9808	1.92	52,535	51,526	1.158	59,667
52....	767	120	412.2	2,756	1,619	.9797	2.03	24,623	24,123	1.159	27,958
53....	788	120	410.3	2,645	1,381	.9812	1.88	22,132	21,716	1.159	25,169
54....	867	120	411.3	4,747	2,702	.9803	1.97	40,190	39,398	1.159	45,662
55....	571	120	410.6	3,445	4,240	.9850	1.50	39,236	38,649	1.159	44,794
56....	579	119	411.3	3,280	2,926	.9834	1.66	36,595	35,987	1.160	41,745
57....	600	120	411.3	5,131	4,737	.9830	1.70	58,259	57,268	1.159	66,374
58....	792	120	411.9	7,114	3,801	.9817	1.83	75,603	74,219	1.159	86,030
59....	930	119	411.9	7,172	3,685	.9814	1.86	74,975	73,580	1.160	85,353
60....	1,053	116	411.9	7,359	2,869	.9796	2.04	71,905	70,438	1.163	81,919
61....	598	120	411.9	5,898	4,833	.9824	1.76	68,693	67,484	1.159	78,214
62....	746	120	412.2	8,135	4,319	.9789	2.11	84,767	82,978	1.159	96,171
63....	791	119	412.9	9,844	3,841	.9778	2.22	97,687	95,518	1.161	110,896
64....	827	119	413.5	7,172	2,909	.9770	2.30	71,261	69,621	1.161	80,830
65....	727	120	412.9	7,747	2,140	.9795	2.05	76,621	75,050	1.160	87,058
66....	895	120	411.9	7,818	4,175	.9802	1.98	77,158	75,630	1.159	87,655
67....	774	121	412.2	6,922	3,085	.9806	1.95	72,298	70,895	1.158	82,096
68....	943	120	412.2	7,945	1,995	.9770	2.30	72,777	71,103	1.159	82,408
69....	675	121	411.9	4,438	3,395	.9796	2.04	49,530	48,519	1.158	56,158

Summary of test of Hohenstein marine

No. of trial.	Approximate fireroom air pressure (inches of water).	Economic results.					Oil fuel per hour.			
		Feed water per pound of oil (pounds), (26)+(22).	Equivalent evaporation from and at 212° F. per pound of oil (pounds), (29)+(22).	Pounds of steam used in spraying oil per pound of oil, (23)+(22).	Steam used in spraying oil (per cent of total steam generated), (23)+(26)×100.	Cubic feet of free air used in spraying oil per pound of oil sprayed.	Oil per hour (pounds), (22)+(8).	Oil per hour per horizontal square foot of furnace (pounds), (35)+50.14.	Oil per hour per square foot of heating surface (pounds), (35)+2130.	Steam consumed in spraying oil (pounds per hour), (23)+(8).
1	10	30	31	32	33	34	35	36	37	38
1......	1.3	11.15	12.70	0.303	2.39	34.3	1,764	35.15	0.83	535
2......	2.3	10.56	12.18	.474	3.89	37.4	2,296	45.8	1.08	1,088
3......	0	12.74	14.43	.153	1.06	62.8	765	15.25	.36	117.5
4......	3.3	10.30	11.73	.337	2.88	36.7	2,867	57.2	1.35	967
5......	0	12.54	14.22	.280	1.97	70	933.6	18.6	.44	262
6......	0	12.36	14.12	.216	1.53	55.4	832	16.6	.39	179.5
7......	0	11.52	13.29	.990	7.45	78.3	1,515	30.2	.71	1,501
8......	3.75	9.39	10.77	.458	4.25	36	3,303	65.9	1.55	1,511
9......	0	12.16	13.89	.701	5.77	0	600	11.97	.28	421
10......	0	11.65	13.47	.464	3.98	0	920	18.34	.43	427
11......	0	11.68	13.45	.515	4.41	0	1,032	20.57	.48	532
12......	0	11.77	13.58	.591	5.03	0	1,122	22.35	.53	663
13......	0	12.43	14.35	1.062	8.54	81.4	962	19.15	.45	1,021
14......	0	12.17	14.06	.742	6.09	78	1,152	22.95	.54	855
15......	0	11.88	13.00	.599	5.26	0	1,009	20.12	.4738	603.9
16......	1	10.16	11.45	.235	2.31	0	1,563	31.17	.7338	367.4
17......	2	8.94	10.19	.157	1.75	0	2,305	45.97	1.0823	361.2
18......	2	9.95	11.32	.297	2.98	0	2,107	42.02	.9893	625.2
19......	3	9.17	10.54	.356	3.89	0	2,978	59.39	1.3983	1,062
20......	1	10.82	12.37	.627	5.80	0	1,969	39.27	.9244	1,235.1
21......	0	12.65	14.42	.963	8.51	0	1,074	21.42	.5042	1,034
22......	0	11.57	13.19	1.098	9.49	16.12	1,085	21.64	.5094	1,190.5
23......	0	11.48	13.11	.977	8.51	0	1,265	25.23	.5940	1,235.6
24......	2	10.022	11.50	.543	5.42	0	1,999	39.86	.9387	1,085.2
25......	2	10.093	11.57	.634	6.29	7.94	1,794	35.78	.8422	1,242.3
26......	2	9.774	11.20	.457	4.68	5.70	1,810	36.10	.8499	828
27......	2	9.881	11.40	.567	5.74	0	2,095	41.78	.9836	1,187.8
28......	2	10.227	11.77	.585	5.72	7.57	1,929	38.47	.9057	1,126.7
29......	2	10.012	11.60	.327	3.27	0	2,040	40.68	.9578	668
30......	1	10.758	12.33	.471	4.38	0	1,694	33.78	.7952	797.8
31......	3	10.285	11.85	.332	3.23	0	2,485	49.56	1.1669	825
32......	0	12.164	13.91	.416	3.42	5.49	954	19.03	.4480	396.7
33......	0	12.335	14.09	.487	3.95	7.18	920	18.35	.4320	448.5
34......	0	11.783	13.46	1.050	8.92	11.48	1,136	22.66	.5334	1,190.5
35......	1	10.794	12.37	.745	6.90	7.96	1,713	34.17	.8042	1,276.5

water-tube boiler, burning oil—Continued.

	Water per hour.					Chimney gas analysis.			
No. of trial.	Feed water per hour (pounds), (26) ÷ (8).	Water per hour corrected for quality of steam (pounds), (27) ÷ (8).	Equivalent evaporation from and at 212° F. per hour (pounds), (29) ÷ (8).	Equivalent evaporation from and at 212° F. per hour per horizontal square foot of furnace (pounds), (41) ÷ 50.14.	Equivalent evaporation from and at 212° F. per hour per square foot of heating surface (pounds), (41) ÷ 2130.	Carbonic acid, CO_2 (per cent).	Oxygen, O (per cent).	Carbonic oxide, CO (per cent).	Nitrogen, N (per cent by difference).
1	39	40	41	42	43	44	45	46	47
1....	19,663	19,327	22,400	447	10.5	6.97	8.77	1.50	82.76
2....	24,232	23,745	27,975	558	13.1	6.96	9.20	1.20	82.64
3....	9,750	9,593	11,041	220	5.18	7.24	10.2	.425	82.135
4....	29,535	28,972	33,633	671	15.8	7.50	10.4	.3	81.80
5....	11,706	11,540	13,276	265	6.23	7.70	10	.13	82.17
6....	10,280	10,125	11,750	234	5.52	7.68	10.25	.06	82.01
7....	17,447	17,360	20,137	402	9.45	10.1	6.64	.275	82.985
8....	31,001	30,629	35,560	709	16.7	7.87	9.66	.22	82.25
9....	7,294	7,228	8,333	166	3.91	5.5	13.05	.27	81.18
10....	10,724	10,669	12,396	247	5.82	6.99	11.05	.013	81.95
11....	12,057	11,985	13,899	277	6.52	7.47	10.66	.086	81.78
12....	13,193	13,128	15,230	303	7.15	8.44	9.29	.014	82.26
13....	11,951	11,914	13,796	275	6.48	7.70	9.85	.075	82.37
14....	14,014	13,986	16,196	323	7.60	8.53	9.04	.05	82.38
15....	11,484	11,311	13,121	261.7	6.16	8.03	9.60	.33	82.04
16....	15,881	15,420	17,903	357.1	8.40	6.57	11.43	.18	81.82
17....	20,604	20,233	23,490	468.5	11.03	7.30	10.73	.43	81.54
18....	20,957	20,580	23,852	475.7	11.20	6.98	9.96	.12	82.99
19....	27,298	26,807	31,391	626.1	14.74	8.6	10.4	.8	80.20
20....	21,309	20,968	24,343	485.5	11.43	8.73	8.73	.1	82.44
21....	12,153	11,922	15,486	308.8	7.27	7.86	9.27	.035	82.83
22....	12,538	12,337	14,311	285.4	6.72				
23....	14,515	14,297	16,584	330.8	7.79	8.3	11.1	.5	80.10
24....	20,032	19,651	22,992	458.5	10.79	6	11.3	.8	81.90
25....	19,755	19,380	22,655	451.8	10.63	5.7	11.9	.8	81.60
26....	17,691	17,320	20,281	404.5	9.52				
27....	20,700	20,265	23,893	476.5	11.22				
28....	19,690	19,237	22,661	452	10.64				
29....	20,424	19,934	23,662	471.9	11.11	6.9	11.9	.33	80.87
30....	18,218	17,781	20,875	416.3	9.80	7.8	10.5	.07	81.63
31....	25,561	24,896	29,452	587.3	13.83	7.3	10	.7	82
32....	11,611	11,425	13,276	264.8	6.23	6.5	12.2	.02	81.28
33....	11,350	11,157	12,965	258.6	6.09	6.3	12.2	.1	81.40
34....	13,355	13,137	15,252	304.2	7.16				
35....	18,492	18,057	21,199	422.8	9.95				

Summary of test of Hohenstein marine

		Economic results.						Oil fuel per hour.		
No. of trial.	Approximate fireroom air pressure (inches of water).	Feed water per pound of oil (pounds), (26)÷(22).	Equivalent evaporation from and at 212° F. per pound of oil (pounds), (29)÷(22).	Pounds of steam used in spraying oil per pound of oil, (23)÷(22).	Steam used in spraying oil (per cent of total steam generated, (23)÷(26)×100.	Cubic feet of free air used in spraying oil per pound of oil sprayed.	Oil per hour (pounds), (22)÷(8).	Oil per hour per horizontal square foot of furnace (pounds), (35)÷50.14.	Oil per hour per square foot of heating surface (pounds), (35)÷2180.	Steam consumed in spraying oil (pounds per hour), (23)÷(8).
1	10	30	31	32	33	34	35	36	37	38
36......	2	10.375	11.92	0.685	6.60	7.32	1,965	39.19	0.9226	1,345.4
37......	3	9.729	11.23	.536	5.51	5.75	2,317	46.21	1.0878	1,242
38......	0	11.925	13.57	.519	4.35	0	1,219	24.31	.5723	624
39......	0	10.943	12.51	.576	5.27	0	976	19.47	.4582	562
40......	0	11.298	12.92	.439	3.88	0	1,197	23.88	.5620	526
41......	0	11.252	12.87	.354	3.15	0	1,093	21.80	.5132	387
42......	2	9.330	10.57	.255	2.74	0	1,645	32.81	.7724	420
43......	1	9.838	11.16	.320	3.25	0	1,398	27.88	.6564	447
44......	3	9.138	10.36	.216	2.37	0	2,002	39.93	.9400	433
45......	3.7	10.350	11.84	.310	2.99	0	2,615	52.16	1.2280	810
46......	0	11.731	13.39	1.180	10.06	0	720	14.36	.3381	849
47......	1	11.238	12.82	.600	5.34	0	1,311	26.15	.6155	787
48......	0	11.321	12.88	1.172	10.36	0	762	15.20	.3578	893
49......	1	10.606	12.10	.770	7.26	0	1,303	25.99	.6118	1,004
50......	3	9.800	11.19	.644	6.57	0	2,007	40.03	.9424	1,293
51......	3	9.055	10.29	.551	6.08	0	1,450	28.92	.6808	799
52......	3	8.935	10.14	.587	6.57	0	1,378	27.47	.6471	809
53......	3	8.367	9.52	.522	6.24	0	1,323	26.38	.6212	690
54......	3	8.467	9.62	.569	6.72	0	1,582	31.55	.7429	901
55......	0	11.389	13.00	1.231	10.81	0	861	17.17	.4043	1,060
56......	0	11.158	12.73	.892	7.99	0	820	16.35	.3850	731
57......	0	11.355	12.94	.923	8.13	0	855	17.05	.4014	790
58......	1	10.629	12.09	.534	5.03	0	1,423	28.38	.6680	760
59......	2	10.453	11.90	.514	4.19	0	1,793	35.76	.8418	921
60......	3	9.772	11.13	.390	3.99	0	2,453	48.93	1.1516	956
61......	0	11.648	13.26	.820	7.04	0	983	19.61	.4615	805
62......	1	10.422	11.82	.531	5.09	0	1,627	32.45	.7638	864
63......	2	9.924	11.27	.390	3.93	0	1,969	39.27	.9244	768
64......	3	9.936	11.27	.406	4.08	0	2,391	47.68	1.1228	969
65......	2	9.892	11.24	.276	2.79	0	1,937	38.63	.9094	535
66......	3	9.870	11.21	.534	5.41	0	2,606	51.97	1.2237	1,892
67......	0	10.444	11.86	.446	4.27	0	1,154	23.01	.5418	514
68......	3	9.159	10.37	.251	2.74	0	2,648	52.81	1.2433	665
69......	0	11.162	12.66	.765	6.86	11.55	1,109	22.12	.5207	849

water-tube boiler, burning oil—Continued.

	Water per hour.					Chimney gas analysis.			
No. of trial.	Feed water per hour (pounds), (26) ÷ (8).	Water per hour corrected for quality of steam (pounds), (27) ÷ (8).	Equivalent evaporation from and at 212° F. per hour (pounds), (29) ÷ (8).	Equivalent evaporation from and at 212° F. per hour per horizontal square foot of furnace (pounds), (41) ÷ 50.14.	Equivalent evaporation from and at 212° F. per hour per square foot of heating surface (pounds), (41) ÷ 2130.	Carbonic acid, CO_2 (per cent).	Oxygen, O (per cent).	Carbonic oxide, CO (per cent).	Nitrogen, N (per cent by difference).
1	39	40	41	42	43	44	45	46	47
36....	20,384	19,888	23,428	467.3	11	....	....	....	....
37....	22,540	21,974	26,018	518.9	12.22	6.7	12.3	0.1	80.9
38....	14,343	14,083	16,322	325.5	7.66	....	....	....	....
39....	10,670	10,510	12,202	243.3	5.73	7.4	10.6	.1	81.9
40....	13,527	13,334	15,468	308.5	7.26	7.85	10.4	.075	81.675
41....	12,293	12,119	14,059	280.3	6.60	7.3	11.1	.2	81.4
42....	15,344	14,969	17,379	346.6	8.16	....	....	....	....
43....	13,748	13,438	15,588	310.9	7.32	4.8	13.2	.6	81.4
44....	18,291	17,853	20,728	413.4	9.73	7	11	.4	81.6
45....	27,064	26,420	30,964	617.5	14.54	5	14	.2	80.8
46....	8,444	8,301	9,637	192.2	4.53	7.1	12	0	80.9
47....	14,735	14,494	16,813	335.3	7.89	6.7	12.4	.1	80.8
48....	8,624	8,458	9,811	195.7	4.61	7.7	14.2	2.1	76
49....	13,820	13,584	15,771	314.6	7.40	8.6	11	1.1	79.3
50....	19,670	19,302	22,448	447.7	10.54	6.6	12.6	.4	80.4
51....	13,134	12,882	14,917	297.5	7	4.6	14.3	.2	80.9
52....	12,312	12,062	13,979	278.8	6.56	5	14	0	81
53....	11,066	10,858	12,585	251	5.91	4.8	14.4	0	80.8
54....	13,397	13,133	15,221	303.5	7.15	4.8	13.4	.6	81.2
55....	9,809	9,662	11,199	223.3	5.26	6	12.8	0	81.2
56....	9,149	8,997	10,436	208.1	4.90	6	12.8	0	81.2
57....	9,710	9,545	11,062	220.6	5.19	6.7	10.9	.2	82.2
58....	15,121	14,844	17,206	343.2	8.08	7.2	11.4	.3	81.1
59....	18,744	18,395	21,338	425.6	10.02	5.8	12.6	.2	81.4
60....	23,968	23,479	27,306	544.6	12.82	7.2	11.6	.4	80.8
61....	11,449	11,247	13,036	260	6.12	6.6	12	0	81.4
62....	16,953	16,596	19,234	383.6	9.03	6.4	12.5	.2	80.9
63....	19,537	19,101	22,179	442.3	10.41	6.4	12	.1	81.5
64....	23,754	23,207	26,943	537.4	12.65	8.6	10.8	.2	80.4
65....	19,155	18,763	21,765	434.1	10.22	6	12	0	82
66....	25,719	25,210	29,218	582.7	13.72	8.6	10.2	.6	80.6
67....	12,050	11,816	13,683	272.9	6.42	8.2	10	.2	81.6
68....	24,259	23,701	27,469	547.8	12.90	7	12	0	81
69....	12,382	12,130	14,046	280.1	6.59	7.8	10.4	0	81.8

Summary of test of Hohenstein marine

No. of trial.	Approximate fireroom air pressure (inches of water).	Pounds of dry chimney gas per pound of carbon. [11(44) + 8(45) + 7(46) + 7(47)] + [3(44) + 3(46)].	Percentage of carbon in oil by chemical analysis.	Pounds of dry chimney gas per pound of oil, (48) × (49).	Heat balance, or distribution of the heating value of the oil. In British thermal units. Heat absorbed by the boiler. (31) × 965.7.	Loss due to superheated steam used in spraying oil.	Loss due to moisture formed by the burning of hydrogen.	Loss due to heat carried away in dry chimney gases.	Loss due to incomplete combustion of carbon.
1	10	48	49	50	51	52	53	54	55
1......	1.3	28.99	83.26	24.1	12,250	0	1,440	3,375	1,495
2......	2.3	30.11	83.26	25.1	11,760	0	1,480	3,925	1,242
3......	0	32.15	83.26	26.8	13,930	0	1,350	2,565	469
4......	3.3	31.64	83.26	26.4	11,320	0	1,540	4,720	326
5......	0	31.54	83.26	26.3	13,720	0	1,370	2,800	141
6......	0	31.91	83.26	26.6	13,620	0	1,390	3,020	66
7......	0	24	83.26	20	12,830	0	1,470	2,945	224
8.....	3.75	30.54	83.26	25.4	10,400	0	1,620	5,480	230
9......	0	42.47	83.26	35.4	13,413	58	1,866	2,990	395
10......	0	35.16	83.26	29.3	13,008	77	1,445	3,500	16
11......	0	32.64	83.26	27.2	12,989	79	1,458	3,410	97
12......	0	29.29	83.26	24.4	13,114	93	1,479	3,270	14
13......	0	31.70	83.26	26.4	13,857	125	1,431	3,000	82
14......	0	28.85	83.26	24	13,578	112	1,465	3,070	49
15......	0	29.57	83.26	24.62	12,551	87.2	1,469	3,217	333.6
16......	1	36.43	83.26	30.33	11,056	41.6	1,502	4,269	225.3
17......	2	31.90	83.26	26.56	9,840	39	1,585	4,745	470
18......	2	34.66	83.26	28.86	10,930	72.8	1,588	5,150	142.8
19......	3	26.41	83.26	21.99	10,177	122.7	1,692	4,952	719.2
20......	1	28.16	83.26	23.44	11,944	146.4	1,568	3,992	957.5
21......	0	31.29	83.26	26.05	13,923	142.8	1,485	3,510	37.4
22......	0	....	83.26	....	12,736	....	1,484	....	....
23......	0	28.19	83.26	23.47	12,657	172.1	1,525	3,530	480.2
24......	2	36.04	83.26	30.01	11,105	120.5	1,581	5,140	994.2
25......	2	37.68	83.26	31.37	11,172	....	1,567	5,210	1,040
26......	2	....	83.26	....	10,815	....	1,547	....	....
27......	2	....	83.26	....	11,006	131.9	1,595	....	....
28......	2	....	83.26	....	11,363	....	1,560	....	....
29......	2	34.10	83.26	28.39	11,202	65.8	1,564	4,619	385.7
30......	1	31.41	83.26	26.15	11,904	80.6	1,535	3,786	75.1
31......	3	30.80	83.26	25.64	11,440	73.1	1,581	4,381	739.4
32......	0	37.74	83.26	31.42	13,433	....	1,471	3,581	25.9
33......	0	38.40	83.26	31.97	13,605	....	1,463	3,672	132
34......	0	....	83.26	....	12,994	....	....	....	....
35......	1	....	83.26	....	11,947	....	....	....	....

water-tube boiler, burning oil—Continued.

No. of trial.	Heat balance, or distribution of the heating value of the oil.								Efficiency.	
	In British thermal units.		In percentages of the total heating value of the oil.							
	Other losses—due to unconsumed hydrogen, to heating moisture in air, to radiation, etc., by difference.	Heat value of one pound of oil, calculated from chemical analysis.	Heat absorbed by boiler.	Loss due to superheating steam used in spraying oil.	Loss due to moisture formed by the burning of hydrogen.	Loss due to heat carried away in dry chimney gases.	Loss due to incomplete combustion of carbon.	Other losses—due to unconsumed hydrogen, to heating moisture in air, to radiation, etc., by difference.	Of boiler (per cent), $[(51)+(57)] \times 100 = (58)$.	Of boiler and furnace (per cent), $(64) \times \left[1-\frac{(33)}{100}\right]$.
1	56	57	58	59	60	61	62	63	64	65
1....	921	19,481	62.8	0	7.4	17.3	7.7	4.8	62.8	61.3
2....	1.074	19.481	60.3	0	7.6	20.1	6.4	5.6	60.3	58
3....	1,167	19,481	71.5	0	6.9	13.2	2.4	6	71.5	70.7
4....	1,575	19,481	58.1	0	7.9	24.2	1.7	8.1	58.1	56.4
5....	1,450	19,481	70.4	0	7	14.4	.7	7.5	70.4	69
6....	1,385	19,481	69.9	0	7.1	15.5	.3	7.2	69.9	68.8
7....	2,012	19,481	65.8	0	7.5	15.1	1.2	10.4	65.8	60.9
8....	1,751	19.481	53.4	0	8.3	28.1	1.2	9	53.4	51.1
9....	1,259	19,481	68.9	.3	6.9	15.4	2	6.5	68.9	64.9
10....	1,435	19,481	66.7	.4	7.4	18	.1	7.4	66.7	64.1
11....	1.448	19,481	66.7	.4	7.5	17.5	.5	7.4	66.7	63.8
12....	1,511	19,481	67.3	.5	7.6	16.8	.1	7.7	67.3	63.9
13....	986	19,481	71.1	.6	7.4	15.4	.4	5.1	71.1	65
14....	1,207	19,481	69.7	.6	7.5	15.7	.3	6.2	69.7	65.4
15....	1,822	19,481	64.43	.448	7.54	16.51	1.713	9.352	64.43	61.04
16....	2.387	19,481	56.74	.214	7.71	21.91	1.156	12.255	56.74	55.42
17....	2,802	19,481	50.51	.2	8.14	24.36	2.413	14.383	50.51	49.62
18....	1,597	19,481	56.11	.374	8.15	26.44	.733	8.199	56.11	54.48
19....	1,818	19.481	52.2	.63	8.69	25.42	3.692	9.333	52.2	50.59
20....	873	19.481	61.31	.752	8.05	20.49	4.916	4.482	61.31	57.74
21....	383	19,481	71.47	.733	7.62	18.02	.192	1.966	71.47	65.39
22....		19,481	65.37		7.62				65.37	59.16
23....	1.117	19,481	64.98	.883	7.83	18.12	2.465	5.733	64.98	59.45
24....	540	19,481	57.01	.616	8.12	26.38	5.104	2.772	57.01	53.91
25....	492	19.481	57.34		8.04	26.75	5.338	2.525	57.34	53.73
26....		19,481	55.51		7.94				55.51	52.91
27....	6,748	19,481	56.5	.677	8.19			34.635	56.5	53.25
28....		19,481	58.33		8.01				58.33	54.98
29....	1,644	19,481	57.5	.338	8.03	23.71	1.98	8.438	57.5	55.61
30....	2,111	19,481	61.11	.414	7.88	19.44	.38	10.836	61.11	58.45
31....	1,266	19,481	58.73	.375	8.12	22.49	3.795	6.5	58.73	56.88
32....	970	19,481	68.96		7.55	18.38	.133	4.979	68.96	66.61
33....	609	19,481	69.83		7.51	18.85	6.777	3.126	69.83	67.07
34....		19,481	66.7						66.7	60.75
35....		19,481	61.33						61.33	57.09

Summary of test of Hohenstein marine

No. of trial.	Approximate fireroom air pressure (inches of water).	Pounds of dry chimney gas per pound of carbon. [11(44) + 8(45) + 7(46) + 7(47)] ÷ [3(44) + 3(46)].	Percentage of carbon in oil by chemical analysis.	Pounds of dry chimney gas per pound of oil. (48) × (49).	Heat balance, or distribution of the heating value of the oil.				
					In British thermal units.				
					Heat absorbed by the boiler. (81) × 965.7.	Loss due to superheated steam used in spraying oil.	Loss due to moisture formed by the burning of hydrogen.	Loss due to heat carried away in dry chimney gases.	Loss due to incomplete combustion of carbon.
1	10	48	49	50	51	52	53	54	55
36......	2	....	83.26	....	11,514	....	....	....	....
37......	3	36.23	83.26	30.16	10,844	....	1,555	4,777.2	124.2
38......	0	....	83.26	....	13,104	....	....	....	....
39......	0	32.90	83.26	27.39	12,078	83.75	1,487.1	3,463.8	112.6
40......	0	31.20	83.26	25.98	12,476	81.77	1,515.4	3,603.5	79.9
41......	0	32.90	83.26	27.39	12,423	65.48	1,464.5	3,549.5	225.4
42......	2	....	83.26	....	10,206	55.72	1,517.5	....	....
43......	1	45.21	83.26	37.65	10,772	67.49	1,481.3	5,538	938.9
44......	3	33.29	83.26	27.72	10,000	53.52	1,517.8	4,563.5	456.8
45......	3.7	47.06	83.26	39.18	11,434	72.62	1,558.3	6,722.2	325
46......	0	34.76	83.26	28.94	12,930	74.22	1,384.8	2,597.7	....
47......	1	36.24	83.26	30.17	12,382	71.16	1,431.3	3,447	124.3
48......	0	25.34	81.52	20.66	12,435	87.77	1,340.3	1,997.9	1,773
49......	1	25.61	81.52	20.87	11,686	75.37	1,412.8	2,189	938.3
50......	3	35.19	81.52	28.68	10,802	127.37	1,526.4	4,453.2	472.8
51......	3	50.88	81.52	41.47	9,932	103.42	1,553.3	6,269.5	344.8
52......	3	48.94	81.52	39.89	9,796	122.86	1,549.4	6,510	....
53......	3	50.94	81.52	41.52	9,188	114.53	1,562	6,995	....
54......	3	45.23	81.52	36.87	9,289	146.38	1,593	6,822	919.2
55......	0	40.94	81.52	33.37	12,556	141.80	1,329.2	3,828.2	....
56......	0	40.94	81.52	33.37	12,292	106.13	1,333.6	3,932.5	....
57......	0	35.64	81.52	29.05	12,493	119.15	1,345	3,569.7	239.7
58......	1	32.90	81.52	26.82	11,679	118.16	1,447.6	4,402	330.9
59......	2	40.88	81.52	33.32	11,492	147.77	1.521.7	6,549	275.7
60......	3	32.48	81.52	26.47	10,752	135.17	1,587.6	5,978.2	435.4
61......	0	37.29	81.52	30.39	12,807	114.46	1,344	3.515.2	....
62......	1	37.28	81.52	30.38	11,416	111.89	1,423.2	4,695.2	250.7
63......	2	37.83	81.52	30.84	10,878	90.59	1,447	5,107	127.3
64......	3	28.23	81.52	23.01	10,883	101.28	1,466.6	....	188.1
65......	2	40.89	81.52	33.33	10,853	58.34	1,413	....	....
66......	3	26.98	81.52	21.99	10,828	144.52	1,547.8	....	539.6
67......	0	29.48	81.52	24.03	11,451	103.38	1,460.4	3,954.5	196.9
68......	3	35.23	....	....	10,016	78.54	1,562.1	....	....
69......	0	31.69	....	....	12,225	....	1,396.5	....	....

water-tube boiler, burning oil—Continued.

No. of trial.	Heat balance, or distribution of the heating value of the oil.								Efficiency.	
	In British thermal units.		In percentages of the total heating value of the oil.							
	Other losses—due to unconsumed hydrogen, to heating moisture in air, to radiation, etc., by difference.	Heat value of one pound of oil, calculated from chemical analysis.	Heat absorbed by boiler.	Loss due to superheating steam used in spraying oil.	Loss due to moisture formed by the burning of hydrogen.	Loss due to heat carried away in dry chimney gases.	Loss due to incomplete combustion of carbon.	Other losses—due to unconsumed hydrogen, to heating moisture in air, to radiation, etc., by difference.	Of boiler (per cent), $[(51) \div (57)] \times 100 = (58)$.	Of boiler and furnace (per cent), $(64) \times \left[1 - \frac{(88)}{100}\right]$.
1	56	57	58	59	60	61	62	63	64	65
36....	....	19,481	59.11	....	....	....	....	....	59.11	55.2
37....	2,181	19,481	55.66	....	7.98	24.53	0.637	11.196	55.66	52.58
38....	....	19,481	67.27	....	....	....	....	....	67.27	64.35
39....	2,256	19,481	62.01	0.43	7.63	17.78	.578	11.581	62.01	58.73
40....	1,724	19,481	64.03	.42	7.78	18.5	.41	8.85	64.03	61.55
41....	1,753	19,481	63.77	.336	7.52	18.22	1.157	9	63.77	61.77
42....	7,702	19,481	52.39	.286	7.79	....	....	39.537	52.39	50.95
43....	683	19,481	55.28	.346	7.60	28.43	4.819	3.506	55.28	53.49
44....	2,889	19,481	51.34	.275	7.79	23.43	2.345	14.831	51.34	50.12
45....	0	19,481	58.70	.373	8	34.51	1.668	0	58.7	56.94
46....	2,494	19,481	66.36	.381	7.11	13.33	....	12.803	66.36	59.68
47....	2,025	19,481	63.56	.365	7.35	17.7	.638	10.395	63.56	60.16
48....	1,033	18,667	66.62	.47	7.18	10.7	9.498	5.534	66.62	59.71
49....	2,366	18,667	62.62	.404	7.57	11.73	5.027	12.675	62.62	58.07
50....	1,285	18,667	57.87	.682	8.18	23.86	2.533	6.884	57.87	54.07
51....	464	18,667	53.22	.554	8.32	33.59	1.847	2.486	53.22	49.98
52....	689	18,667	52.48	.658	8.3	34.88	....	3.692	52.48	49.03
53....	807	18,667	49.23	.614	8.37	37.48	....	4.323	49.23	46.15
54....	0	18,667	49.76	.784	8.54	36.54	4.925	0	49.76	46.42
55....	812	18,667	67.27	.76	7.12	20.51	....	4.35	67.27	59.99
56....	1,003	18,667	65.85	.569	7.16	21.07	....	5.375	65.85	60.59
57....	900	18,667	66.93	.638	7.21	19.12	1.284	4.822	66.93	61.49
58....	689	18,667	62.57	.633	7.76	23.58	1.773	3.692	62.57	59.42
59....	....	18,667	61.57	.792	8.15	35.09	1.477	0	61.57	58.99
60....	....	18,667	57.59	.724	8.51	32.03	2.333	0	57.59	55.29
61....	887	18,667	68.61	.613	7.20	18.83	....	4.752	68.61	63.78
62....	770	18,667	61.16	.599	7.62	25.15	1.343	4.125	61.16	58.04
63....	1,017	18,667	58.28	.485	7.75	27.36	.682	5.448	58.28	55.99
64....	6,028	18,667	58.30	.543	7.86	....	1.008	32.3	58.3	55.93
65....	....	18,667	58.14	.313	7.57	....	....	....	58.14	56.52
66....	5,607	18,667	58	.763	8.29	....	2.891	30.04	58	54.86
67....	1,501	18,667	61.35	.554	7.83	21.19	1.055	8.041	61.35	58.73
68....	....	....	53.67	.421	8.37	....	....	....	53.67	52.19
69....	....	....	65.49	....	7.48	....	....	....	65.49	60.99

TESTS OF CENTRIFUGAL BURNERS.

While experiments were being conducted with representative types of steam and air burners under the Hohenstein boiler, the possibility of using mechanical burners was given special consideration by the board. Some independent experiments were projected with centrifugal burners, and it is a matter of regret that other important work devolving upon each member of the board prevented extended consideration of this matter.

As the possibility of spraying oil by means of centrifugal force looked inviting, two burners were built for experiment. In both burners the principle of the turbine was utilized as being obviously a practicable way of securing a high rotative speed in a simple manner. These burners were designed by Mr. Harvey D. Williams, who was then secretary of the board.

In the burner shown in fig. 26, the attempt was made to support the revolving part on a film of the steam discharged from the turbine buckets. This method of support was unsatisfactory, owing to some obscure action of the steam which caused the revolving part to gyrate excessively.

The burner shown in fig. 27 was designed so as to utilize a ring of buckets that was formerly part of an experimental steam turbine. In this steam turbine there were five rings like the one used in the burner. The turbine was compounded in such a way that the outputs of power from the five rings were equal. The turbine, at a speed of 15,000 revolutions per minute, gave 20 horsepower, with a consumption of about 20 pounds of steam per horsepower hour. By the use of diverging steam nozzles the single ring, as used in the burner, should give an efficiency somewhat higher than one-fifth that of the compounded turbine. In other words, the burner turbine should, at a speed of 15,000 revolutions per minute, yield more than 1 horsepower on 100 pounds of steam per hour.

In designing the burner, however, the consumption of steam was assumed at 400 pounds per horsepower hour. This was to allow, among other contingencies, for the unknown viscosity resistance of the thin film of oil flowing from the center of the disk to the periphery. Even with this seemingly ample allowance only one-ninth as much steam should be required as in the simple jet burner.

The following brief notes, made each day during the tests with centrifugal burners, will probably best tell of the results accomplished and of the possibilities of development in this direction:

SOLID PIVOT CENTRIFUGAL BURNER.

October 27, 1902.—First official test using burner of form shown in fig. 27, but without the large spraying disk which was added later. Piped for steam and oil. Steam at 125 pounds gauge pressure. Nozzles

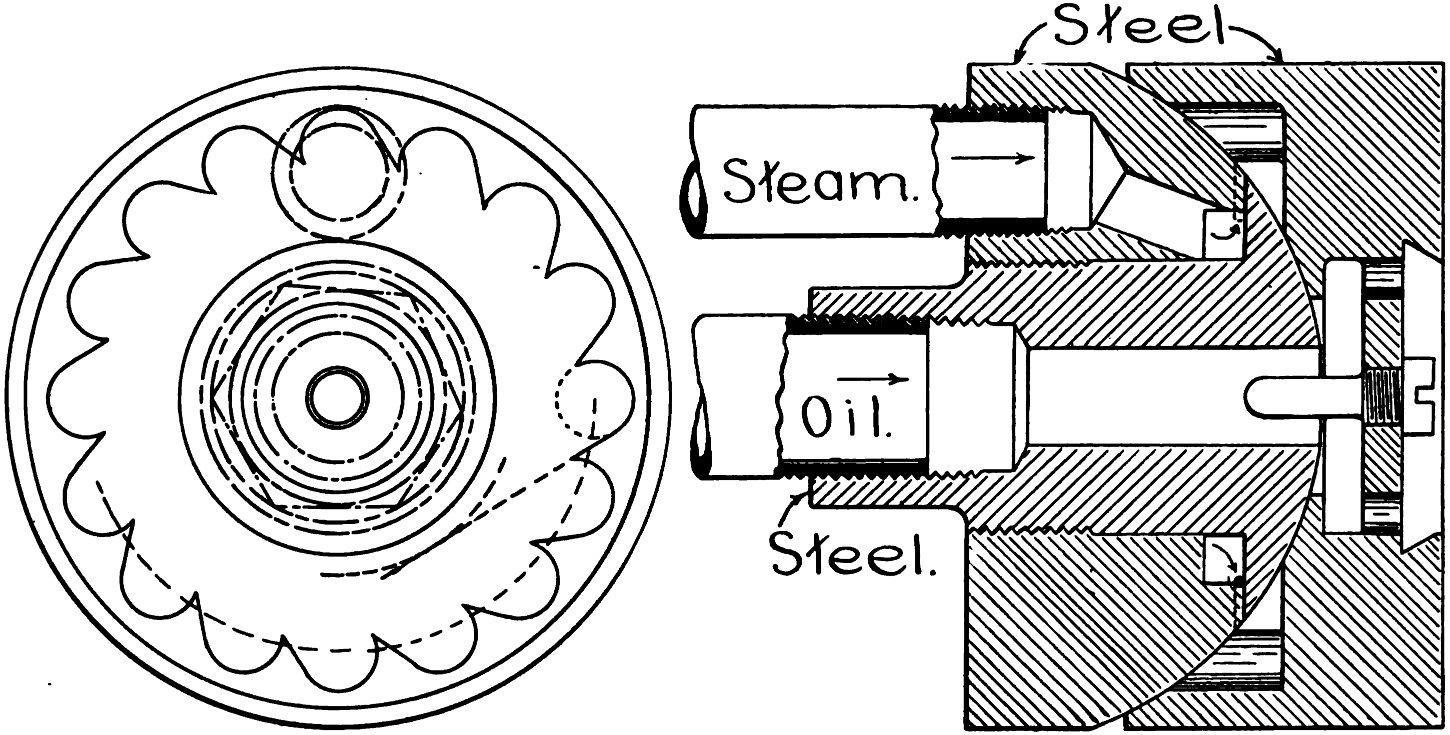


FIG. 26.—Experimental centrifugal burner, steam pivot.

proportioned for 90 pounds gauge pressure. Turned on steam. Action of turbine and pivot very satisfactory. Turned on oil. Some oil seemed to escape from the bottom of the rotating part. Oil thrown off from milled edge was sucked downward, forming dome-shaped sheet of mist, edges of which met turbine buckets. Applied torch. Burner enveloped in flames. Flames rather gusty. Smoke varied with quantity of oil. Turned off oil and steam. Turbine ruined, half of the buckets having been ruptured by centrifugal force. The buckets were probably at a red heat, however. Buckets collided with brass nozzle tips and beveled them off.

STEAM PIVOT CENTRIFUGAL BURNER.

October 28, 1902.—First official test using burner of form shown in fig. 26. Piped for steam and oil. Turned on steam. Top did not revolve. Allowed some minutes for burner to warm up to temperature of steam. Steam film afforded a frictionless support, as expected, but top would rotate only slowly. Steam orifices are too small (8 by 1/32 by 1/32 inches), and some of them are stopped up with dirt. Broke pipe connections. About a quart of unburnt oil on the ground where the burner stood. During the following day the steam pivot burner was dismantled, and the size of the steam passages was increased to about 1/16 by 1/16 inch, giving them also rounded entrances and tapered exits.

October 29, 1902.—Piped for steam and oil. Turned on steam. Top spun at a high rate of speed, but gyrated excessively. Gyration was against the rotation, i. e., like that of a body whose center of gravity is below the point of support. Hence gyration was not the effect of gravitation and must have been the effect of some action of the steam. Top offered a good deal of resistance to being lifted off the pivot when rotated by steam. Resistance appeared to be at least two or three times its weight. Bushed the hole in the pivot to reduce amplitude of gyration. Gyration not prevented; only reduced. Drove a wooden plug in the oil hole and made a solid pivot. Top spun perfectly. Cut a groove in plug to allow passage of oil. Turned on steam and oil. Applied torch. Burner worked properly. Oil ignited about 6 inches from burner. Outside diameter of flame 4 or 5 feet. Flames seemed inclined to go out when torch was withdrawn, possibly due to the wind, which was quite brisk. When not ignited the burner makes a shrill, squealing noise. When ignited there is added a roar, due to the flames. When flow of oil was increased, the top was lifted as much as 3 inches from pivot and continued to spin on the jet of oil. When flow of oil was again reduced, the top fell back onto the pivot without mishap.

October 30, 1902.—Made a solid step of brass for pivot to spin on, the same as in the solid pivot burner. Made a disk 10 inches in diam-

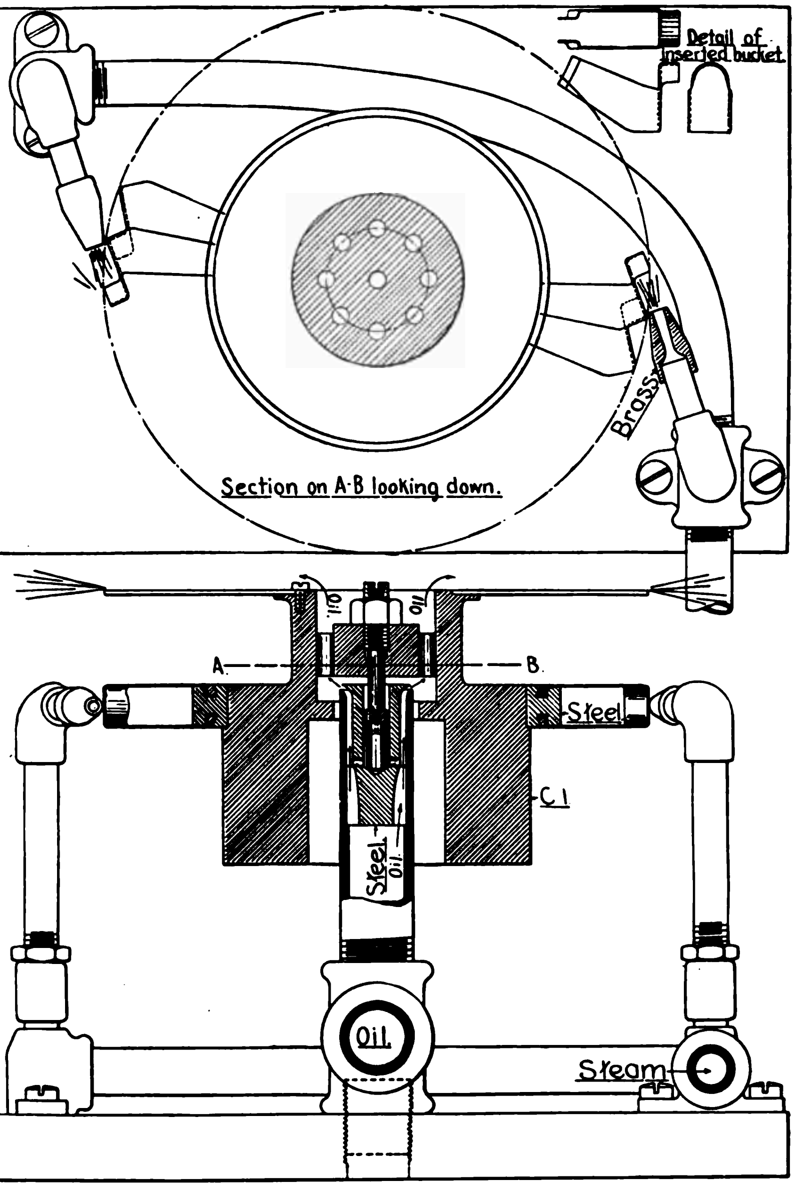


Fig. 27.—Experimental centrifugal burner, solid pivot design.

eter of stovepipe iron and fitted it for fastening onto either burner with two ¼-inch screws.

October 31, 1902.—Both burners now having solid pivots they will be referred to as the 8-jet burner (originally the steam-pivot burner) and the double-jet burner.

The 8-jet burner.—Piped for steam and oil. Built a cylindrical furnace 4 feet in diameter and 4 feet high of loose brick, arranged as solid checkerwork, around the burner as a center. The plane of spray was about 14 inches above the ground. Openings were left near the ground for the entrance of air, and fire bricks were built in at the level of spraying. There were eighteen air openings about 6 inches wide by 8 inches high, equal to 864 square inches. Behavior of top satisfactory. Turned on a very little oil and caught specimen of spray on blotting paper. Turned on more oil and ignited. Steam pressure, 80 to 90 pounds. Steam very wet. Oil pressure, 15 to 25 pounds. Oil pressure fluctuated about 5 pounds with each stroke of oil pump. Combustion occurred in puffs or gusts at intervals of two or three seconds. Gusts did not time with strokes of pump or with anything else that was noticed. Under these conditions the smoke was moderate. With more oil the gusts did not occur, but the smoke increased greatly. Oil and steam were varied by manipulation of valves with no noteworthy results. The experiment continued perhaps half an hour, until the brickwork became very hot, though not red-hot. Turned off oil and steam. Top was in perfect order and continued to spin a long time. The inside of brickwork was perfectly clean. There appears to be no tendency to deposit carbon. The outside of the brickwork was, however, black from the smoke and flames that came through the crevices.

At the beginning of the experiment there was a chimney (12 by 12 inches outside dimensions) built of loose brick around the burner from the ground up to within about 1 inch of the spraying plane. The object of the chimney was to protect the burner and piping from radiant heat. But the chimney top appeared to suck the spray downward, partly into contact with itself. The chimney was, accordingly, tumbled down with an iron rod while the burner was in operation. The result was that the oil was now all burnt, whereas before much of it collected on the top of the chimney and ran down it to the ground.

Double jet burner.—During the interim cleared nozzle orifices, drove on a new bucket rim, and reduced width of oil slot to about $\frac{1}{32}$ inch. Piped for steam and oil. The burner has the 10-inch sheet-iron disk for increasing the size of the spraying circle. Rebuilt furnace 4 feet in diameter and about 3 feet 3 inches high. Air openings, 18 by 6 by 4 inches, equal 432 square inches. Turned on steam. The pressure at the boiler was 90 pounds. The turbine worked beautifully. Threw in a piece of burning oil-soaked waste. Turned on oil. The combustion is much better than ever before. Free from gusts. Little smoke. There is, however, no wind, a condition not had in any previous experiment. So much heat was developed that it was inconvenient to stand within 12 feet of the furnace. One could not continually stand by the steam and oil valves. After about three minutes something connected with the burner suddenly gave way. Shut off oil; the 10-inch sheet-iron disk had exploded. The oil flowed over the bottom of the disk, leaving the top unprotected from the heat. One side of the fractured disk was black with oil, while the other side was blue from the heat. The buckets of the turbine were apparently unchanged. Turned on steam again, adjusting quantity so that turbine gave about the same whistling note that it gave during the combustion experiment. A violin was brough from the U. S. S. *Rodgers*, and after tuning it was found that the turbine note was one octave above the open E string. There are 32 buckets on the turbine. This makes the speed of the turbine about 2,500 R. P. M.*

November 3, 1902.—Made a disk of sheet iron $\frac{1}{16}$-inch thick and 10 inches diameter, and fastened to burner in such manner that the oil flows over its upper surface. Assembled burner and repaired circular furnace, making it 33 inches high and 4 feet in diameter. Tried burner at 5 p. m. It seemed to work satisfactorily in all respects. The oil was able to protect the disk from overheating during the few minutes that the experiment lasted. Speeded up turbine without igniting oil and caught samples of spray on blotting paper.

November 8, 1902.—Repaired brick wall. Steam at 90 pounds. Oil at 25 pounds. Turned on steam. The burner began spinning all right and soon attained speed. Ignited some kerosene-soaked waste and dropped it beside the burner. Turned on oil. There was instant ignition. Stepped aside to observe the effect. More oil was being supplied to the burner than it could take and spray properly. Much oil was escaping downward from the burner. Could not shut off the oil at the valve on account of the intense heat. Ordered it shut off at the pump. Oil continued to flow on account of the air chamber on the pump. Something exploded and demolished one side of the furnace. The turbine ring had broken loose. The ring was merely driven onto the cast-iron center. The heat and centrifugal force had been sufficient to expand it to the degree of making it loose. When free it tore off the 10-inch disk. The cast-iron center continued to spin for some time. Half the buckets were torn off the turbine ring. The 10-inch disk can be used again.

November 11, 1902.—Burner again ready for trial. A new turbine ring has been driven on and fastened with three $\frac{1}{4}$-inch screws. The

---

*It was unfortunate that we had not a more reliable means of determining the speed, since this result seems questionable. The buckets of the turbine could safely withstand 15,000 revolutions per minute, and at such a speed, barring mishaps, the spraying would have been far more effective.

10-inch disk is fastened as before. Oil passageways through the cast-iron center have been somewhat enlarged.

November 15, 1902.—Assembled the 2-jet burner and connected pipes as heretofore. Instead of a brick wall around the burner, two curved boiler plates from the scrap pile were used. The lower edges of the plates were lifted off the ground by the thickness of three bricks. The plates made an inclosure about 5 feet in diameter and 4 feet high. Turned on steam from the main boiler. Placed some oil-soaked waste on the ground within the inclosure and ignited it. Oil pump started and orders given to keep oil pressure at about 20 pounds. When the oil valve was opened there was instantly an intense combustion within the inclosure. The heat was so great that the oil supply had to be reduced. The volume of the fire was as easily controlled at the valve as in a common gas jet. After about five minutes the burner went to pieces, caused by the backing out of the supporting pipe where it screws into the pipe fitting on the pedestal.

Summary.—The steam pivot burner was a failure from the start, and it is not considered advisable to attempt to correct all its faults.

The solid pivot burner failed at first because the oil was not thrown off from its greatest diameter, and afterwards because some of the oil escaped downward and burnt underneath, thus heating the burner, and finally from the parts not being securely fastened together.

CONCLUSIONS AS TO CENTRIFUGAL BURNERS.

First. The oil should be thrown off from the largest diameter of the burner.

Second. The burner must be so arranged that the only outlet from the oil leads to the intended spraying edge. The construction of the experimental burner was such that part of the oil went wrong when the amount fed was greater than a certain maximum or less than a certain minimum.

Third. The oil should be introduced at the center of the spraying disk and flow over the whole of the surface exposed to the radiant heat.

Fourth. All parts should be secured by fastenings, which are more reliable than mere friction, however great; otherwise the very high speed of rotation will shake them loose.

Fifth. There is no evidence that the amount of oil flowing through the burner is not amply able to keep it at a safe temperature. In fact, the cooling power of the oil compared to the amount of surface of the burner is many times greater than the cooling power of water compared to the heating surface of a boiler. The ratio is from 25 to 200 or 300 in favor of the oil.

Sixth. By leading the air required for combustion in along the burner head or burner mechanism, the inrush of air can itself be made to absorb much of the heat which the disk receives from radiation, the air thus constituting a cooling medium to the mechanism.

Seventh. These experiments were all conducted in the open air and some of them in a wind. Hence there was little of the benefits derivable from the presence of glowing furnace walls. How much this affected the result is, of course, uncertain, but it is the opinion of many who witnessed the experiments that the presence of hot furnace walls would have resulted in a very great improvement.

PROPOSED CENTRIFUGAL BURNER.

Mr. Williams, the designer of the foregoing burners, after careful study of the principles involved and the results of these tests, designed a new burner which is shown in fig. 28, but the construction of this burner was not completed in time to be experimented with before the conclusion of the main series of boiler tests. However, as designed, this proposed burner shows many features which it is known can be employed in forming a successful means to atomize oil by centrifugal action.

In this burner but one disk is used, this disk constituting both the spraying edge and the medium to carry the steam turbine buckets. The buckets are riveted to the disk of saw steel in a circle one inch within the edge of the disk. The steam turbine nozzle is located within the circle of buckets, and blows its steam outwards, as shown in the upper part of the figure. To gain economy in steam consumption the precise form of the De Laval nozzle or tuyere is used, which nozzle it may be said has the property of increasing the velocity of the issuing steam to its highest point, and the buckets passing within this jet of high velocity have imparted to them the energy derived from the jet. The amount of steam used is so small that one jet should be amply sufficient to exert all the centrifugal force required to effect the necessary vaporization with oils of usual consistency. The pivot itself is arranged so as not to require any outside lubrication, this being effected by a small by-pass of the oil to the outside sleeve of the fixed pivot.

The fuel oil, under a slight pressure from the pump, is caused to pass up through the center of the mechanism to the top of the spraying head. It is here caught by the rapidly whirling disk and flung away with high velocity from the revolving edge. This passage of oil over the disk constitutes in a measure a cooling jacket to protect the metal of the disk from the intense radiation of the furnace from above. Cooling on the under side of the disk is effected by taking in a portion of the air supply through a flared opening in the grate immediately under the revolving disk. The action of the furnace draft, together with the steam blast created by the steam tuyere, tend to produce a sharp flow of air immediately under the rapidly revolving portion of the disk.

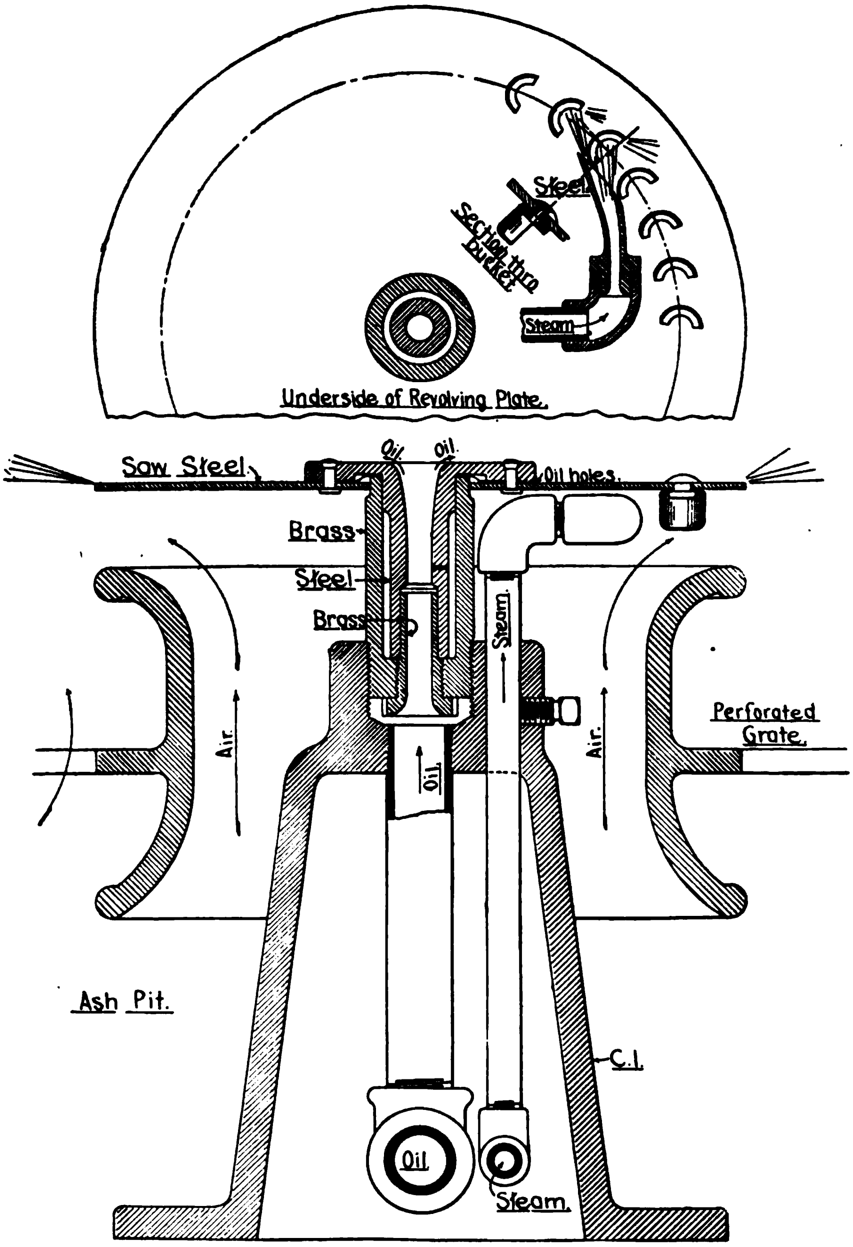


FIG. 28.—Proposed Williams centrifugal burner, solid pivot.

The burner as thus constructed would naturally be regulated by controlling the oil supply, the entrance of steam being kept at a point to insure the maximum rotation of the disk.

In the practical introduction of these burners into fire boxes they would probably be located in the center of grates of square fire-box furnaces, and the air supply would be brought in, as indicated, mainly around the burner, and additional air, as needed, through proper openings in the grate. For purpose of use in furnaces of Scotch boilers it would be desirable to place the rotating head in the end of the furnace casting, and require the disk to revolve in a vertical plane. With small-size Scotch furnaces it would be necessary to reduce the diameter of the disk and increase the speed of rotation by use of one or more steam jets.

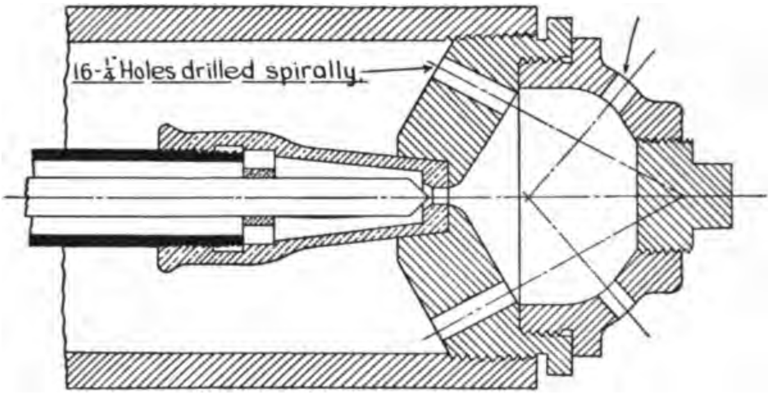


FIG. 29.—*Burner No. 1.*—In this burner it was found that with a pressure of 5 pounds the appliance worked well. The flame was very short and combustion good. When the pressure was below 5 pounds the operation of the burner was not satisfactory, as the flame was not circular and oil dripped considerably.

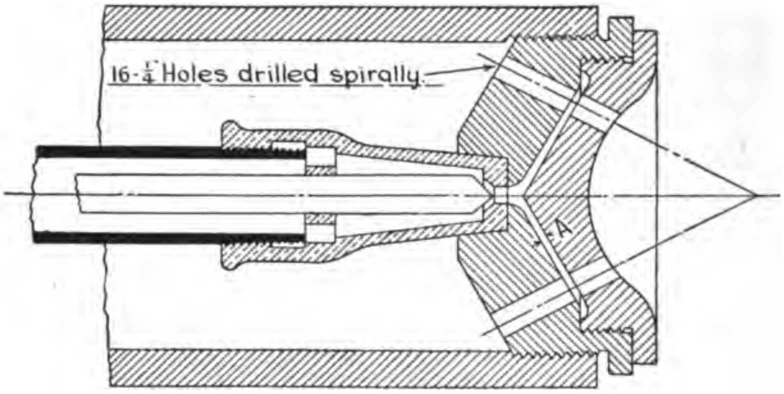


FIG. 30.—*Burner No. 2.*—With this burner the pressure of air could be reduced to about 1 pound. The atomizing of the oil was exceedingly satisfactory. The flame was very short and mild, showing a decided improvement over burner No. 1. The efficiency of this burner was due in part to the very shallow mixing chamber, which is marked "A" on the drawing. With this arrangement the oil flowed in very thin streams into the path of the issuing air. There was a satisfactory mixing of oil and air, thus insuring complete combustion. This burner has recently been tried by using steam as the atomizing agent and satisfactory results have been secured.

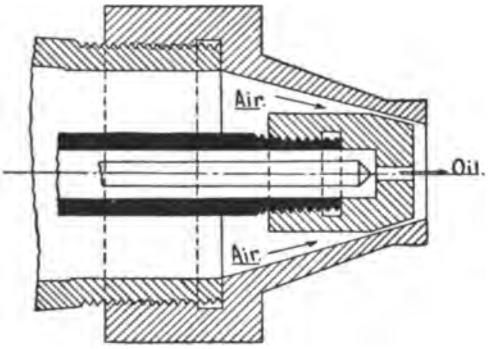


FIG. 31.—*Burner No. 3.*—This burner could not be used with pressures lower than 12 pounds. With a pressure of 20 pounds for atomizing purposes, the appliance worked very well, but complete combustion was not effected near the front of the furnace. There was also excessive roaring noise when such high pressures were used, thus making it objectionable for general use.

SUPPLEMENTARY EXPERIMENTS CONDUCTED.

As a direct result of the preliminary report submitted by the board, there were special experiments conducted by individuals, and in many cases the general results of these experiments have been submitted to the Bureau of Steam Engineering. Attention is called to the several designs of plugs used in a series of tests, which were made under the direction of the marine engineering experts of the New York Shipbuilding Company, of Camden, N. J., to ascertain the effect of spraying the oil through various sized holes drilled spirally through a plug or cap fitted to the end of various burners. It may be incidentally stated that the steamers *Nevadan* and *Nebraskan*, plying between San Francisco and Honolulu, are equipped with burners wherein such distributing plugs are fitted. This series of tests, conducted under the special direction of Mr. L. D. Lovekin, of the New York Shipbuilding Company, undoubtedly established the fact that efficient results could be secured by reducing the size and increasing the number of the holes drilled through the end plug, taking particular care, however, that the holes should be drilled spirally at an angle that would permit a short and evenly distributed flame and one well spread near the burner end. The various modifications of plugs are shown in the appended sketches with the general results obtained after comparative experiment with the several designs.

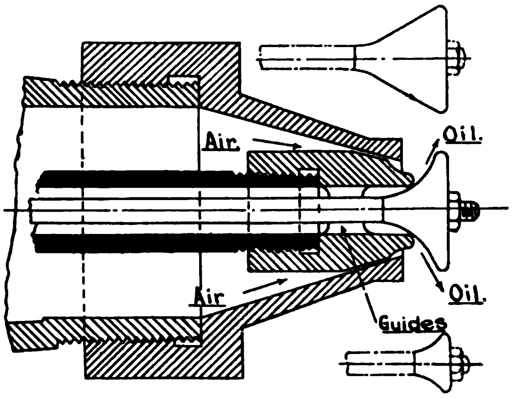


FIG. 32.—*Burner No. 4.*—In order to obviate the difficulty experienced with burner No. 3, several forms of deflectors were made, which resulted in reducing the length of the flame in the furnace. It was also found with these deflectors that the atomizing pressure could be reduced. The fact that the roaring noise could not be obviated even with deflectors showed the disadvantage of this particular type. At no time could fairly good combustion be secured with this design where the atomizing pressure was less than 10 pounds.

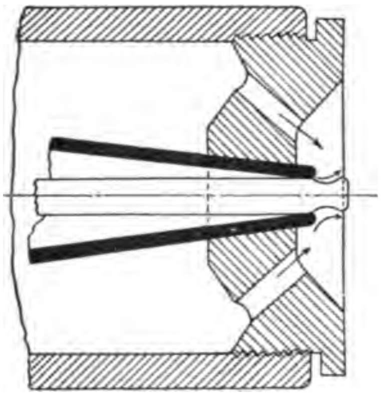


Fig. 33.

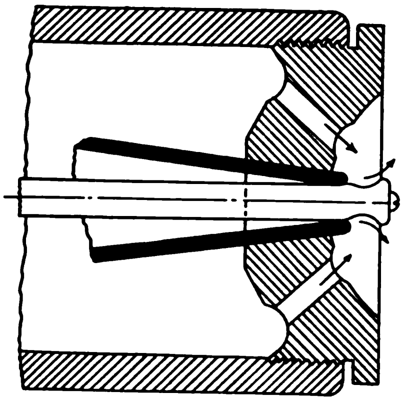
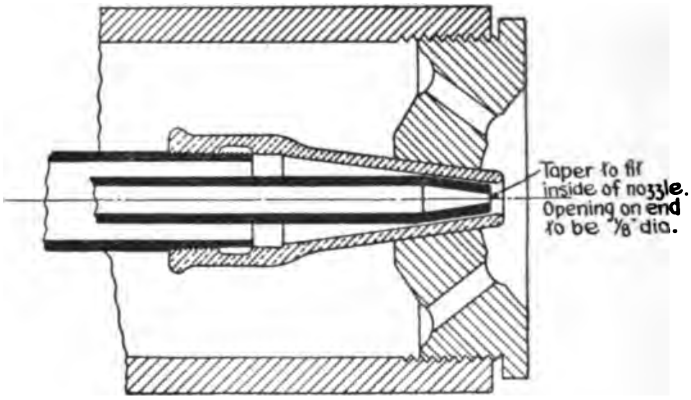


Fig. 33a.

FIGS. 33 and 33a.—*Burners Nos. 5 and 6.*—The only difference in these burners is in the modification of their tips. These minor changes were made to notice the effect of curving the ends of the deflectors. The result showed no appreciable difference in effect. It was also found with this form of plug that the oil would flow very unevenly. The absence of a central guide for the steam in both these designs possibly interfered with the satisfactory operation of the appliance.



Taper to fit inside of nozzle.
Opening on end to be 1/8" dia.

FIG. 34.—*Burner No. 7.*—This burner was designed to note the effect of installing a central tube. It was a development of burners Nos. 5 and 6. The results obtained showed the benefit of having such an arrangement. With a central tube it was shown that with the proper manipulation steam of 25 pounds pressure would be sufficient for atomizing purposes.

EXTENT OF RESEARCH WORK AND INVESTIGATION CONDUCTED BY THE BOARD.

In the investigation of the important problem of attempting to determine the value of liquid fuel for naval purposes the board made special effort to note the development as regards the use of liquid fuel secured by the industrial and maritime world. The oil-fuel installations of several ocean-going steamers were carefully examined under actual working conditions. The installations projected by various promoters were critically inspected. The operation of various patented oil-fuel devices installed at several industrial establishments were reported upon, so that the board could ascertain by comparative observation and study the trend of development of oil-burning under various conditions both for manufacturing and marine purposes.

Hundreds of letters have been received from technical experts throughout the country, and the conclusions reached by the board represent a vast amount of research, investigation, and experiment. The board can unhesitatingly state that both upon the part of the engineering profession and of skilled labor there is a general desire to have oil supplant coal as a fuel for practically every purpose. The prejudice in favor of oil is so great that it is strikingly significant that the general public is told very little concerning the disadvantages, but is repeatedly reminded of every advantage accruing from the use of oil as a fuel. The desire to use liquid fuel thus practically exists everywhere. When manufacturers, however, attempt to secure some guaranty that the numerous promises made as to reduced cost and assured supply will turn into performances, then become manifest the hindrances to the use of oil as a fuel. It may also be said that up to the present time, except upon the Pacific coast and in certain portions of the East Indies, the more carefully shipowners inquire into the financial, structural, and transportation features of the oil-fuel problem, the less inclined they are to dispense with the use of coal in the furnaces of their boilers.

THE OIL-FUEL INSTALLATION OF THE STEAMSHIP MARIPOSA.

The board believes that the observation and report of Lieut. Commander Ward P. Winchell, U. S. Navy, as to the installation of oil-fuel appliances on board the steamship *Mariposa* should be considered in connection with this extended series of tests, since the data secured in regard to the performance of that vessel was collected with exceeding care, this officer having made the round trip on the vessel as the representative of the Bureau of Steam Engineering, Navy Department.

The extent and character of the information secured by this officer suggests the advisability of detailing other officers for special duty of this nature. The board is of the opinion that if several commissioned officers could be employed continuously in this work for one or two years there could be secured sufficient reliable information to justify the Department taking decided action as to the advisability of exclusively equipping even a large-sized warship with an oil-fuel installation.

The board, after making inquiry, has been impressed with the number of officers who are ready to volunteer for such work, and who are specially fitted for this particular duty, and there is no doubt but that naval interests would be subserved by such details.

As it can be expected that several mercantile vessels will make the round voyage between the Pacific and the Atlantic coast during the coming year, using oil exclusively as a fuel, the board specially recommends that arrangements be perfected whereby a commissioned officer could be detailed to the special duty of observing and reporting upon the effectiveness of every oil-fuel installation subjected to such extended service.

THE VOYAGE OF S. S. MARIPOSA, USING AN OIL-FUEL INSTALLATION EXCLUSIVELY UNDER HER BOILERS.

The following is a description of the steamer *Mariposa*, of the Oceanic Steamship Company, as fitted for oil-fuel burning, with an account of the preliminary trial trips of the vessel as witnessed by Captain H. N. Stevenson, U. S. Navy; also the report of Lieut. Commander Ward P. Winchell, U. S. Navy, who officially represented the Department on the round trip of the steamer between San Francisco and Tahiti.

REPORT OF CAPTAIN H. N. STEVENSON, U. S. NAVY, ON THE OIL-BURNING FITTINGS OF THE S. S. MARIPOSA.

The *Mariposa* is a single-screw iron steamer, built at the yard of William Cramp & Sons, Philadelphia, Pa., in 1883. She recently had new engines and boilers installed by the Risdon Iron Works, San Francisco, Cal., the oil-burning plant having been installed by the same company.

This vessel has been employed in the Pacific trade, and is now running to Tahiti from San Francisco, making the round-trip voyage of 7,320 knots each month.

Description of the Mariposa.

Gross tonnage		3,160
Length between perpendiculars	feet..	314
Beam	do....	41
Mean draft	do....	22
Depth of hold	do....	$17\frac{3}{12}$

There is a single bottom with four water-tight athwartship bulkheads, and two masts, square rigged on the foremast.

The total crew was formerly 81, but since the change from coal to oil burning 16 men have been taken out of the engineer's force, reducing the crew to 65 men and making the engineer's force for oil burning 20 men, as follows: 1 chief engineer, 3 assistant engineers, 3 oilers, 1 electrician, 1 attendant for ice machine, 1 attendant for air compressor, 3 water tenders, 6 firemen, 1 storekeeper; total, 20.

THE ENGINES AND BOILERS.

There is one triple-expansion engine of the inverted direct-acting type, with cylinders 29 inches, 47 inches, and 78 inches by 51-inch stroke, designed for 2,500 indicated horsepower, fitted with piston valves on the high pressure and intermediate pressure and slide valve on the low-pressure cylinders, all driven by link motion. The condenser is part of the back framing. The cylinders are not jacketed.

The air, feed, and bilge pumps, of which there are two sets, are driven from the forward and after crossheads. The centrifugal circulating pump is driven by a separate engine. The 4-bladed propeller is 16 feet 6 inches diameter and has a pitch of 23 feet.

There are three cylindrical tank boilers placed fore and aft in the line of the ship—two are double ended, 15 feet 3 inches diameter by 17 feet 3 inches long, and one single ended, 14 feet diameter by 9 feet 9 inches long, the latter placed amidships forward of and worked from the forward fireroom. Each double-ended boiler has six corrugated furnaces; the double-ended boilers have a common combustion chamber for opposite furnaces, while the single-ended one has a common combustion chamber for its three furnaces. There is one smokestack for all the boilers. The combustion chambers of the double-ended boilers have a brick bridge wall, and the back sheet of the single-ended one is covered with fire brick. The decision to use oil in place of coal was not made until the changes in engines and boilers were well under way, and it was decided to put the ship on the route to Tahiti. The steam pressure averages 180 pounds. There is one auxiliary boiler, two-furnace return-tube type, in upper fireroom hatch, and fitted to burn coal only.

THE OIL TANKS.

These were constructed out of the old coal-bunker space forward of the boilers, and as the steamer is intended to carry oil for the round trip of about 7,320 miles some additional space had to be taken from the forehold. They are arranged as follows: Just forward of the boiler space a solid water-tight bulkhead, well braced, was built from the berth deck to the single bottom of the ship, extending to the single skin of the ship, from side to side; 4 feet, or two frame spaces, forward of this was also built another similar solid bulkhead, which formed the after ends of the oil tanks; 48 feet farther forward another similar solid bulkhead was built to form the forward ends of the oil tanks, and 4 feet forward of this another solid bulkhead. The spaces of 4 feet at each end of the tanks being a cofferdam space to catch any oil from leakage or accident, these cofferdam spaces can be filled with water if necessary. The tank space is divided into six tanks by a middle bulkhead and two side partitions. Splash plates to break the impact of rolling are placed in each tank, a small opening at the top allowing any accumulation of gas to pass off to the ventilating trunk. Small openings at the bottom allow free communication for the oil. Along the top of the tanks is provided an expansion head or trunk, being 4½ feet high and 4½ feet wide. Over each a ventilating trunk connecting with the top of each tank extends up to about 5 feet above the hurricane deck. The cofferdam spaces are ventilated by tubes reaching to the upper deck, fitted with cowls, one tube reaching to near the bottom to carry off any heavy gas that might accumulate there. From the upper deck the sounding pipes to each tank are reached. There are no pipes in or through the tanks except those connected with the oil service. The total capacity of the tanks, exclusive of expansion trunk, is 6,338 barrels of oil—about 905.43 tons. One barrel of oil equals 42 gallons.

To fill the tanks, on the port side outside the ship a 6-inch hose connection is fitted. From this a pipe leads to the forward fireroom, where the tank oil pump is placed. This pump, horizontal duplex, steam cylinders, 9 inches, oil cylinders 8½ inches, stroke 10 inches, can be used to draw its supply from the pipe and deliver into each of the tanks, or by using by-passes, which are provided, the oil barge alongside can fill all the tanks. An overflow pipe from each tank, carried at height of the deck above them, leads to an overflow outside the ship near the supply-hose coupling.

There are two service or settling tanks placed in pockets formed on either side of the single-ended boiler. They are reached by doors from the forward fireroom. Each of these tanks holds about twelve hours' supply. They are filled by the oil-tank pump and have overflows back to the main tanks. Ventilating tubes lead from near the bottom of the pockets in which they are placed to the smokestack.

Each service tank is provided with glass gauges, by means of which the amount used every hour or watch can be easily measured.

Each settling tank has two suction pipes, one at bottom to draw off water if necessary, the other at a height of about two feet for the oil supply to the service pumps. All the tanks are provided with manholes to reach the interior.

Burner used on S. S. *Mariposa.*

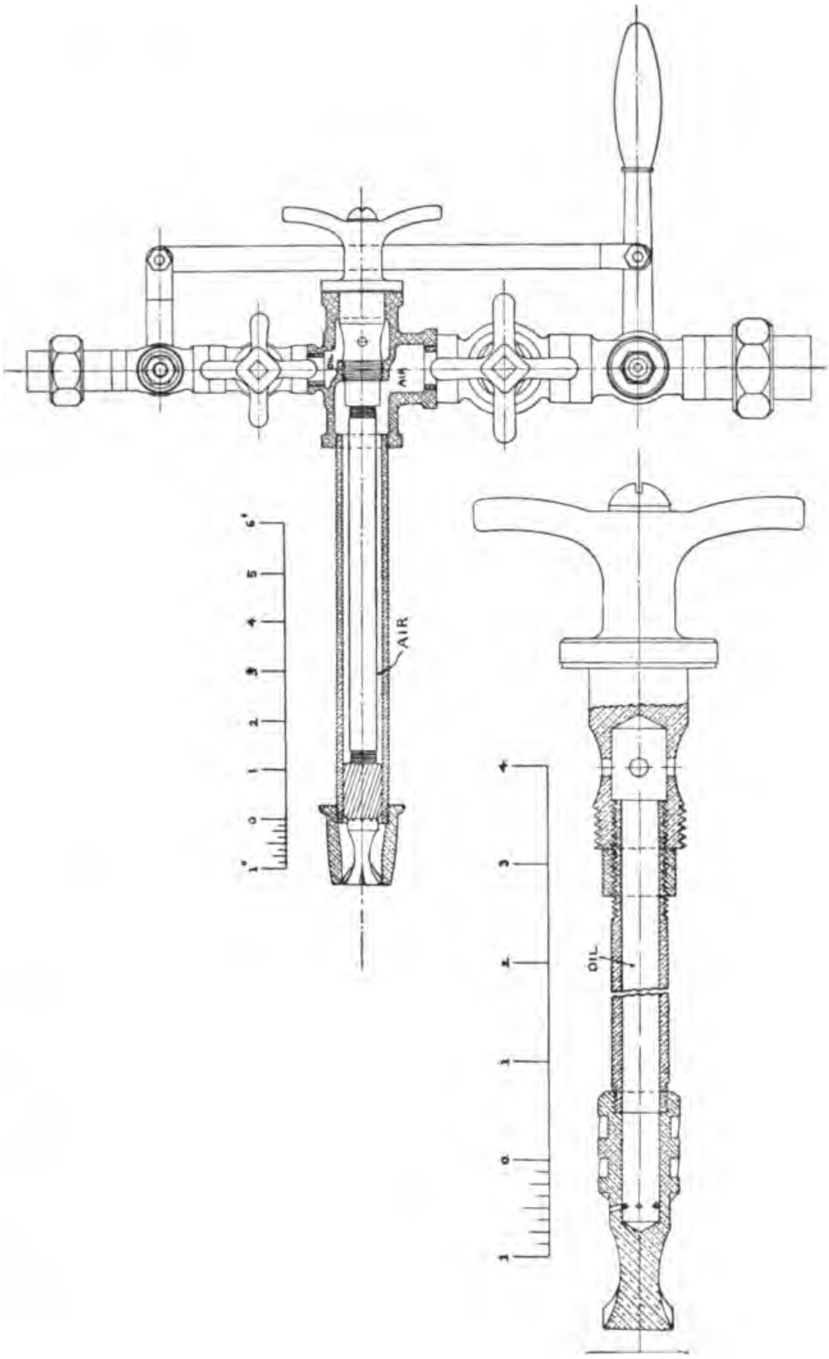


FIG. 35.—The Grundell-Tucker Burner, used on S. S. *Mariposa.*

THE OIL-SERVICE PUMPS.

The oil-service pumps, of which there are two—horizontal duplex, steam cylinders 6 inches, oil cylinders 4 inches, and stroke of 6 inches, one being large enough to supply all the burners—are placed in the forward fireroom on either side. They draw their supply from the settling or receiving tank through removable strainers placed so they can be easily changed for cleaning, and discharge into the bottom of the small heating tank near them, where the oil is heated by a steam coil to not more than 150° F., and thence by a pipe to the burners. The air from the compressors, under a pressure limited to 40 pounds, discharges into the top of the heater tank on its way to the burners, so that the oil and the air go to the burners under the same pressure. The heater tank is provided with glass gauges; also a float to work a telltale and automatic control of oil-supply pump.

THE AIR COMPRESSOR.

The air compressor is placed in a pocket off the upper engine-room platform, and consists of duplicate steam and air cylinders connected to a crank shaft carrying a fly wheel turning between the cylinders. Either set is large enough to supply all the air necessary. The air compressor is horizontal, double-acting, duplex. Air cylinders 22 inches, steam cylinders 12 inches, diameter, by 18-inch stroke for all cylinders. Capacity equals 1,000 cubic feet of free air per minute compressed up to 30 pounds at 120 revolutions per minute. Air is used at the heat of compression or as heated by the air heater.

THE ATOMIZER.

The atomizer, for which patents are pending, is the joint invention of Messrs. Grundell and Tucker, San Francisco.

The atomizer, shown in fig. 35, consists of a hollow plunger for the oil, screwed into a pipe through which the air passes. The outlet for the oil is through a series of small holes at right angles to the central hole; the air meets the oil through spiral directors and is sprayed into a rose shape by the expanded end of the atomizer

The air and oil pipes have globe valves to regulate the supply of either; also plug cocks connected together to a handle, by means of which each burner can be shut off immediately, in case of necessity—a slow-down bell, or other cause. The air-supply pipe is also connected to the steam line so that steam can be quickly substituted for air, if desired. The length of the oil plunger is adjustable, to give the best form to the rose-shaped flame. Two burners are fitted to each furnace.

THE AIR HEATER.

A part of each furnace front is a hollow iron casting, through which the air passes on its way to the atomizers and becomes heated. The chamber surrounding the burner is lined with a crucible lead lining; a by-pass to the burners is provided for use in case of accident to the heater. The lower part of the furnace front is a door on hinges that can be fastened open at any desired degree to give air for combustion. There are also two louvres in the door for the same purpose. Near the front of the furnace inside the door is placed a brick wall made to deflect upward the inward current of air to meet the rose-shaped flame from the burners. There is ample space over the brick wall for a man to enter the furnace through the ash-pit door. The double furnace combustion chambers have a brick bridge wall reaching above the top of the furnaces, and in the single-ended boiler the common combustion chamber has the back sheet covered with fire brick to protect it.

THE TRIAL TRIPS.

Two trial trips with the vessel under way were made on July 5 and 11, the vessel being under way about eight hours each day, running from the vessel's dock to the Farallone Islands and return. These trips were made for the purpose of ascertaining if the oil apparatus, as well as the new engines and boilers, were in good working condition. On the first run the boilers primed badly, owing to the dirt not having been thoroughly cleaned out of them. Before the second run the boilers were cleaned, and then worked well.

The strainers on the oil-supply pipes were not finished, and considerable trouble was found with dirty oil, which clogged the burners. Neither the telltale to show the height of oil in the heater tank nor the controlling device for the oil-service pump were fitted, not being finished in time for use. No attempt was made to measure the amount of oil burned nor to attain the maximum speed, and it was therefore impossible to obtain any data other than observation of the working of the oil apparatus.

Very few of the fire-room force had ever had any experience with oil burners on steamers, and one object of the trials was to give the force practical experience. When properly regulated the burners gave no smoke, but that they were not properly regulated is shown by the fact that more or less smoke was visible most of the time, and at times dense black. Owing to lack of the telltale and regulating device of the small heating tank the pump tender once allowed this tank to fill up and the oil to flow over into the air pipe and flood the burners. As soon as this was discovered every burner was immediately shut off by means of the lever connecting to the plug cocks on the oil and air supply pipes at the burners.

The atomizer tubes were unscrewed and on some of them, where the oil had caked, considerable force had to be applied to pull them out. New, clean atomizers were screwed in, and as soon as the oil-heater tank could be brought to the proper oil level the burners were started again. Some steam pressure was lost during this delay, but the engines did not stop nor slow down very much; some of the burners were started in a few minutes and all of them in less than fifteen minutes. The value of being able to shut off the oil and air quickly and clean or substitute other atomizers was shown by this mishap. The burners made considerable roaring noise, and the air pressure was, in order to clean the burners from dirt, carried at about twice the intended pressure, owing to the inefficiency of the strainers, which allowed dirty oil to choke them. They had to be taken out frequently for cleaning. By shutting off with the lever, the regulating valves were left in adjustment for starting the fire again, provided it was right before. The new fire is started by a torch inserted into the plug hole around the burner.

On the second run the strainers and regulating device for the heater tank had been completed. The oil apparatus was handled with greater ease and uniformity, and the less amount of smoke was very noticeable. For intervals of an hour or more scarcely any or none would be observed. On the run in from the Farallones the engine was speeded up to 74 to 77 turns, and an average speed of 14¼ knots was obtained. The steam pressure was uniformly maintained at the point desired without difficulty, and the oil-burning apparatus gave no trouble whatever and worked well.

The oil used on both runs was from the Kern River district, near Bakersfield, Cal.

The following data was observed:

Steam pressure	pounds..	160–170
Revolutions of engine		74–77
Revolutions of air compressor		60
Pressure of air	pounds..	20
Temperature of oil entering heater	° F..	80
Temperature of oil leaving heater	do....	120–130
Temperature at base of stack	do....	750

It is regretted that the nature of the trials did not permit of obtaining a greater amount of data beyond observing the apparatus in use.

The chemist at the New York navy-yard submitted the following report upon the sample of the Kern River district oil sent him for analysis:

> The sample is practically free from low boiling naphtha, as on distillation only a small percentage passed over below 150° C., and less than 10 per cent below 225° C. A boiling point above 360° C. was reached before the second 10 per cent was collected.
>
> It shows on ultimate analysis the following composition:
>
> | | Per cent. |
> |---|---|
> | Carbon | 84.43 |
> | Hydrogen | 10.99 |
> | Nitrogen | .65 |
> | Sulphur | .59 |
> | Oxygen | 3.34 |
>
> This gives a calorific value, by Dulong's formula, of 18,806 B. T. U. The specific gravity at 60° F. is 0.962. Flash point, 228° F. Fire point, 258° F. Vaporization point, 178° F. Loss for six hours at 212° F., 12.01 per cent.

H. N. Stevenson,
Captain, U. S. Navy.

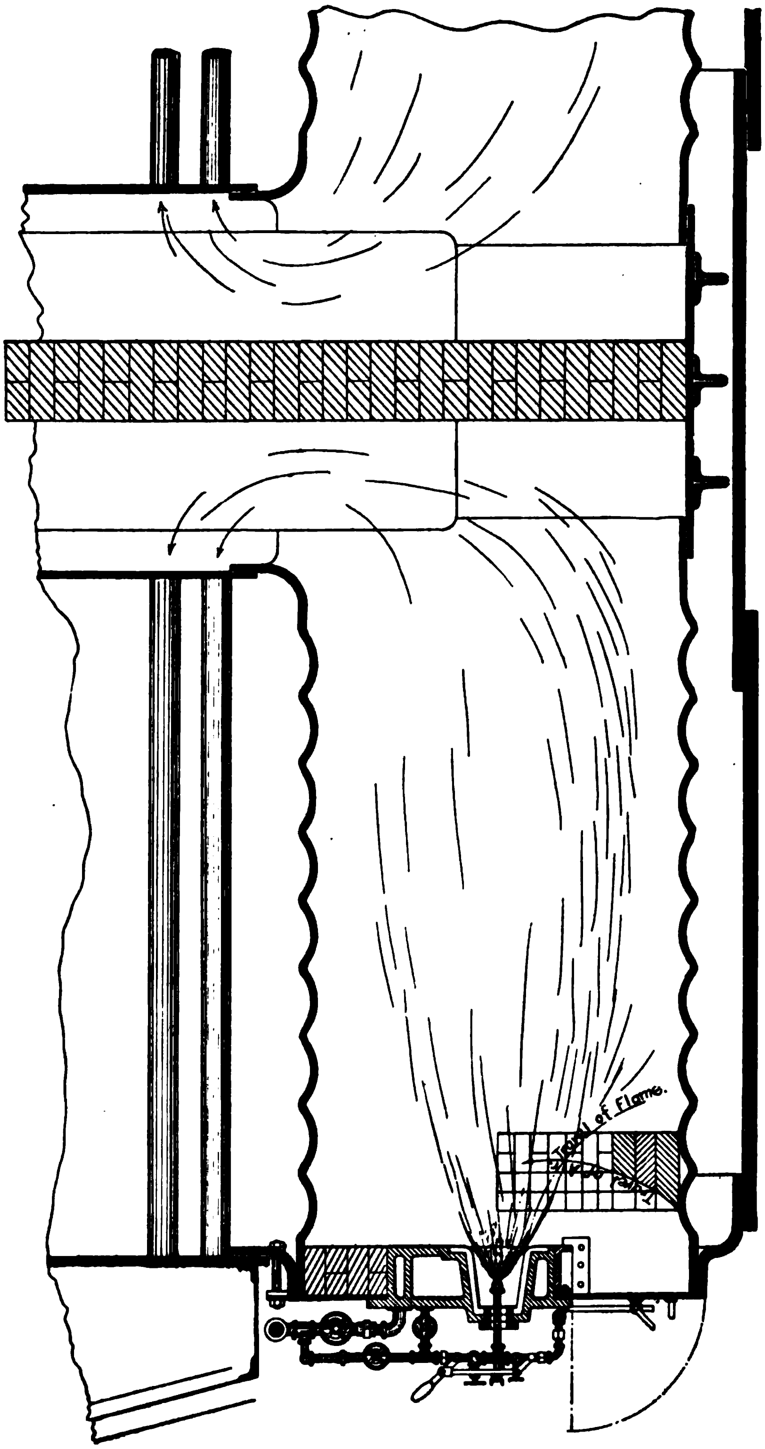


FIG. 36.—Arrangement of furnace for oil burning on S. S. *Mariposa.*

REPORT OF LIEUT. COMMANDER WARD WINCHELL ON THE VOYAGE OF THE MARIPOSA.

U. S. S. BOSTON,
At Sea, August 15, 1902.

SIR: In accordance with the Department's telegraphic order of July 7, 1902, delivered July 8, 1902, and the instructions from the Bureau of Steam Engineering, dated July 7, delivered a few minutes before sailing, I took passage on the Oceanic Steamship Company's steamer *Mariposa*, leaving San Francisco at 10 a. m. July 15, 1902, for the round trip to Tahiti.

In accordance with the instructions of the Bureau, two sets of indicator cards were taken each day, making forty-five sets in all, the data of which were worked up.

There have been no tests to determine the evaporative efficiency of the two main double-ended boilers used on the run, and I regret to report that the chief engineer of the ship was unable to improvise any apparatus by which the amount of feed water could be determined with accuracy enough to give data of any value.

The amount of oil is a matter of much importance, since the tanks hold barely enough to make the round trip, and but one day's supply of coal was aboard. The oil was measured first by the amount pumped into the two settling tanks, as shown in inches on the scale back of the gauge glasses on the tanks; second, this amount was checked by the number of inches used out of each tank for each watch; third, another check, and the one considered most accurate as dealing with large quantities and small errors, was by sounding the tanks from time to time and comparing the amounts taken out with the expenditures in the log. The latter method gave a correction which was applied to the daily log, increasing the daily expenditure slightly, as summed up by inches in the settling tank.

The most careful inspection at Tahiti failed to show any bad effect of the flame upon the boilers. Neither leaks nor defects developed anywhere about them and there was no difficulty at any time in feeding the boilers. Having been ordered to the U. S. S. *Boston* immediately upon my arrival at San Francisco, the opportunity was lost for again inspecting the boilers, but no defects showed from the outside. At Tahiti the tubes were swept by tube scrapers, and back connections, uptakes, ash pans, and furnaces were cleaned. All the refuse from these various places barely filled two ash buckets.

This refuse, mainly soot, was the result not only of the twelve days' run to Tahiti, but also of the three preliminary trials by the contractors. The first one, a four-hour trial of engines and boilers, was made with Comax coal, and the other two were free runs at sea, of about eight hours' duration each, burning oil. The tubes had never been cleaned previous to arrival at Tahiti. It is the intention hereafter to make the round trip of twenty-four days' steaming without sweeping tubes.

There are no precautions other than those usually taken on board ship, to guard against fire or explosion. All spaces to which oil has access are well ventilated by both inlet and outlet ducts. The oil is a thick dark fluid, like molasses, and in the open air burns slowly, giving off much smoke. But it gives off volatile gases which form explosive mixtures with air, tanks empty or nearly so being more dangerous than full ones in this respect. The ship is electrically lighted, but in addition an open hand lamp is burning in the fireroom all the time to light the burners; the firemen smoke on watch, and the oil is treated no more tenderly than if it were coal. On the run back, the cargo of copra was stored all about the expansion trunk, which projects up 4½ feet between decks, completely covering the tanks and making them inaccessible for examination.

Of the 6 firemen, 3 were relieved from watch the second day out, leaving but 1 man on a watch to fire 12 furnaces in two different firerooms separated by the length of the double-ended boilers. The water tender did not touch the burners except in emergency, his duty being to 'tend water, fill settling tanks and record height of oil in them, record temperatures of oil at settling tank and in heater of fireroom and of superheated air, take reading of lower pyrometer where the two uptakes meet, and run oil pump supplying oil to the settling tanks and small oil pump supplying oil to the oil heater.

As a coal burner the *Mariposa* formerly had the following engineer force: 1 chief engineer, 3 assistant engineers, 3 oilers, 12 firemen, 12 coal passers, 3 water tenders, 1 messenger, 1 storekeeper; total, 36.

A reduction of 16 men in the fireroom force is effected by oil burning. At sea she needs now but 3 firemen, but carried 6. This would reduce the force by 19 men.

Temperatures of firerooms seem to be about what one would expect in coal burning, but the temperatures of the uptake and smoke-pipe gases run high, the maximum being 925, which shows an undue loss of heat here. The temperature of the oil in the settling tanks ranged between 68° and 100° F. on the trip out and between 90° and 108° F. on the trip back.

The oil auxiliaries comprise 1 large oil pump, 2 small oil pumps, 2 oil heaters, 1 air compressor, and 4 strainers.

There is a steam-pipe connection to blow out the oil strainers, and another one to blow out the oil burners when clogged.

On August 3 the air compressor needed overhauling, and steam atomizing was kept up for two and one-half hours until the compressor was again working. During this time the evaporator supplied enough feed water to use 20 burners; the engines were not stopped while shifting from steam to air atomizing, and averaged 67.8 turns for the two and one-half hours. They had before been making 70 turns.

At first 2 firemen and a water tender were on watch at a time, each fireman having 1 fireroom of 6 furnaces, or 12 burners. The men had but little experience, combustion was poor, much smoke was made, much oil burned, and poor speed attained. To locate the responsibility for bad adjustment of burner valves, but 1 fireman was put on at a time to attend 12 furnaces (24 burners). This made an improvement in the combustion.

Unfortunately, the top of the funnel can not be seen from either fireroom, and while the fireman can tell by the appearance of the flame as shown in the sight hole, or even by the roar of the burner, when the combustion is perfect, in designing a boiler room for liquid fuel the ventilators should be so arranged that a view of the top of the smoke pipe can be had from each fireroom.

The work of the fireman would be even easier than it is and better results attained if the oil and air pressure were kept constant and the heated temperature of the oil constant. The apparatus then, once properly adjusted, would need very little change. To get these results is a mere matter of detail easily arranged. If the temperature of the oil rises, it feeds more freely and a readjustment is necessary, and the same conditions hold with regard to the pressure.

It will be noticed that in addition to the independent oil and air supply valves the burners are fitted with an air plug cock and an oil plug cock connected to one lever, which then controls both air and oil supply, enabling the operator to shut them both off at once in emergency. At first, when steam went up too high and a burner was shut down this lever was used; but shutting off the air thus gave the air compressor less work, and as its governor is not sensitive the air pressure increased, making a readjustment of all oil and air supply valves necessary, with consequent smoke. Later on, when it was desirable to shut down a burner the oil alone was shut off by the independent feed valve on the burner, and the untouched air valve kept the air compressor's work more nearly constant; then when the burner was again required the oil valve was opened and immediately lighted from the flame of the adjacent burner.

In starting fires with everything cold, steam is raised on the auxiliary boiler, which burns coal, and the air compressor, oil pumps, and oil heater are started. The oil is lighted by inserting oil-soaked rags in the air space surrounding the burner and touching a lamp to them, or an arrangement like a gas lighter may be used.

Sometimes when the air pressure is too high, or insufficient oil is feeding, the flame flickers and may go out. If the oil is kept feeding under these conditions, on relighting there is a small explosion of the gases in the furnace, with a momentary back draft through the peepholes and ash pans.

When shut down July 19, for two and one-half hours, plugging condenser tubes, one burner at each end of each boiler (4 burners in all), furnished steam to run all auxiliaries, including feed pump, bilge pump, air compressor, ice machine, dynamo, and flushing pump, all of which were exhausting into the atmosphere.

During the four days in port at Tahiti the forward main single-end 3-furnace boiler was used, atomizing with steam. Generally two burners in the middle furnace gave ample steam to run the following auxiliaries, all exhausting into the atmosphere, with boiler fed from fresh water on the dock: Ice machine, dynamo, flushing pump, feed injector, 2 cargo winches, and small portable steam pump.

In the Grundell-Tucker burner (see fig. 35) the oil, heated by a steam coil under boiler pressure throttled down, passes through the inside pipe and is thrown out radially through the series of small holes. The air, first heated by compression up to 20 pounds, is further heated to a temperature of about 350° F. in the air chamber surrounding the burner, and called the "air superheater." Air can be used at the temperature at which it leaves the compressor, and was so used on the trip down until July 17, when the superheaters were connected up. This air under the pressure of about 20 pounds surrounds the oil pipe in the burner and passes axially along the pipe until near the end, where it is given a whirling motion through small helical passages arranged like the rifling of a gun. It crosses axially and whirling through the fine oil streams spurting radially from the end of the burner, breaking up the oil into fine spray, the drops of which can be seen before they ignite. A further air supply (cold) is admitted through the hinged door of the ash pan, and is directed up across the path of the flame and heated also by a curved fire-brick wall built in the ash pan close to the front.

This ash-pan door is not moved much, but the regulation of the air supply is by the valve control of the air and oil in the burner. The flame should be a steady, full, white or yellowish white one, filling the furnace.

The principal difficulties encountered were in the regulation of the supply of oil to the heaters by the pump and the consequent variation of the temperature of the heated oil and the freedom of flow through the burners. An automatic submerged float, arranged like a steam trap and fitted in the oil heater to control the throttle of the pump, failed to give good automatic results, and the supply of oil was regulated by hand. If the oil is heated too much (above 150° F.), some of the volatile gases are given off and mingle with the air pressing on top of the oil in the heater, thence passing with the air into the air superheaters and burners, the result being that on one occasion a heater got red hot from this cause.

Another difficulty was due to the choking of the strainers by foreign matter and impurities in the oil, shutting off the supply of oil, and on one occasion (August 10) putting out all the fires. Just previous to the fires going out, and while the usual air supply was on, and an insufficient amount of oil being fed, a dense white smoke, like steam, arose from the funnel.

This strainer difficulty will be solved by fitting the strainers in pairs, so that a clean one can always be switched in while the choked one is being cleaned.

Generally the revolutions of the engines did not vary much during the day, and in calculating the horsepower for each day's average revolutions, when the cards for that day differed much, that set was selected whose revolutions were near the average for the day with the indicated horsepower, assumed to vary as the cube of the revolutions. If the two sets of cards for the day had the same number of revolutions, their average indicated horsepower was used as a basis to compute the day's horsepower as before.

It will be noted that the log accompanying this report is kept from noon to noon. This was done as the patent log was inaccurate, and the speed of the ship was got from noon positions as given by sights.

It will be noted that speed was much higher on the return trip than on the outgoing, which is ascribed partly to the better combustion as the firemen became more experienced, partly to the overhauling of the bearings at Tahiti by the force on board, and mostly to the increased oil consumption allowed after the run down had proved that there was plenty of oil for the return trip, which was a matter of some doubt before, the ship being provided with coal for twenty-four hours to cover possible emergency.

Full power was not developed in the two boilers used, as schedule time was easily exceeded with from 2 to 4 burners shut off, though it would not appear, from the tabulated results, that the indicated horsepower would equal what can be got by a good system of forced draft. This burner, however, works well with the Howden system of forced draft, as seen on the tank steamer *George Loomis*, plying on a Pacific coastwise route, from southern California to San Francisco.

It must be remembered that the tabulated calculations are all based on the indicated horsepower of the main engines only, as it was considered better to use only data actually obtained, and afterwards estimated data, such as indicated horsepower of auxiliaries, could be applied without vitiating the observed data and results. No cards could be taken from any of the auxiliaries, but careful estimates give the following results:

	I. H. P.
Air compressor, at 60 revolutions per minute	110
Auxiliary feed pump and two oil pumps, one in intermittent use	30
Dynamos	30
Ice machine	7
Circulating pump	5
Flushing pump	2
Baths, steam tables, evaporator, cooking, etc	11
Total	195

The steering engine is not used except near port.

The size of air compressor was based on the assumption that it requires 1 cubic foot of free air for every pound of water evaporated from and at 212° F., as shown by tests of various oil burners at Western Sugar Refinery, San Francisco.

The weights of oil auxiliaries are as follows:

	Tons.
Air compressor	9
Two settling tanks	12
Two oil heaters	2
Two oil pumps (small)	.5
One oil pump (large)	1.25
Fifteen superheaters (air), front	3.1
All pipe, valves, fittings, ventilators, etc	8

It should be remembered that the boilers were designed for coal burning; that the oil-burning plant was fitted in a hurry, the machinists not leaving the ship until the gong rang for people to go ashore; that the firemen were without experience in oil burning, and that most of the automatic gear did not function properly.

With the air pressure constant, with the oil heated at constant temperature near 140° F., with oil strainers arranged in pairs, so that one is always efficient, and with experience in firing, the results in economy of oil should be much better on the next trip; and the fireman's work, already very easy, will approach supervising automatic regulation. The fireman for oil does not need strength nor previous training with coal. He should have a good eye, good ear, some common sense, and a desire to learn a new and easy trade.

In conclusion, it is desired to state that every facility for investigation was given by all the officers of the company, the chief engineer of the ship being particularly zealous in arranging for the taking of required data.

Very respectfully,

WARD WINCHELL,
Lieutenant, United States Navy.

To the CHIEF OF BUREAU OF STEAM ENGINEERING,
Navy Department, Washington, D. C.

General summary of log of Mariposa, burning oil, round trip, San Francisco and Tahiti, July and August, 1902.

NOTE.—For convenience in comparing with engineer's log, the day is taken from noon until noon. July 16 begins at noon July 15 and ends noon July 16. This leaves but two hours' run on July 15, which was thrown out of the calculations. The average indicated horsepower of main engines was obtained not by averaging the daily runs, but by taking average revolutions for the eleven days' run, and taking the cards near these revolutions as a basis in computing the horsepower.

Date.	Knots per day.	Knots per hour.	Revolutions per minute.	I. H. P. main engines only.	Oil used per day (barrels).	Oil used per day (tons of 2,240 pounds).	Oil used per hour (pounds).	Grate surface, two double-ended boilers.	Heating surface, two double-ended boilers.	I. H. P. main engines per square foot of grate.	I. H. P. main engines per pound of oil per hour.	Square feet of heating surface per I. H. P.	Pounds of oil per hour per I. H. P.	Pounds of oil per knot run.	Knots made per ton of oil.	Knots made per barrel of oil.	Slip of screw in per cent.	Actual time.	Remarks.
San Francisco to Tahiti.																		*h. m.*	
July 16	289	12.08	58.74	1,475	258	36.86	3,451	258	8,302	5.64	0.427	5.63	2.33	286	7.84	1.12	9	23 55	
July 17	298	12.3	61.1	1,768	260	37.14	3,438	258	8,302	6.85	.51	4.70	1.94	279	8.02	1.15	11	24 12	
July 18	302	12.5	62.5	1,950	260	37.14	3,438	258	8,302	7.55	.57	4.25	1.76	275	8.13	1.16	12	24 12	
July 19	311	12.8	63.4	1,864	260	37.14	3,440	258	8,302	7.20	.54	4.44	1.84	267	8.38	1.20	10.4	24 8	
July 20	285	13.1	65.7	2,200	230	32.86	3,484	258	8,302	8.50	.63	3.77	1.58	258	8.67	1.24	12.1	21 7	July 20 stopped 2¼ hours to plug leaky tubes in condensers.
July 21	321	13.26	65.6	2,396	285	33.60	3,133	258	8,302	9.30	.76	3.60	1.30	234	9.55	1.36	10.8	24 11	
July 22	306	12.6	65.8	2,270	255	36.43	3,365	258	8,302	8.80	.67	3.66	1.48	270	8.40	1.20	15.5	24 15	
July 23	307	12.5	65.7	2,240	240	34.30	3,200	258	8,302	8.70	.70	3.70	1.43	253	8.95	1.28	15.7	24 27	
July 24	335	13.8	68	2,386	250	35.71	3,299	258	8,302	9.20	.72	3.60	1.39	239	9.35	1.34	10.7	24 16	
July 25	351	14.5	69.8	2,470	257	36.71	3,398	258	8,302	9.57	.72	3.36	1.38	234.8	9.59	1.27	8.3	24 11	Jib and fore try-sail set, trade wind port beam.
July 26	333	13.9	69.1	2,129	258	36.86	3,432	258	8,302	8.25	.65	3.90	1.61	244.6	9.03	1.29	11.7	24 3	
Total	3,438	......	......	......	2,803	400.43	......	......	......	......	......	......	......	......	......	......	......	262 57	
Average	......	13.12	65.2	2,193	254.8	36.40	3,412	258	8,302	8.593	.643	3.786	1.556	260.9	8.585	1.22	13.14	......	

General summary of log of Mariposa, burning oil, round trip, San Francisco and Tahiti, July and August, 1902—Continued.

Date.	Knots per day.	Knots per hour.	Revolutions per minute.	I. H. P. main engines only.	Oil used per day (barrels).	Oil used per day (tons of 2,240 pounds.)	Oil used per hour (pounds).	Grate surface, two double-ended boilers.	Heating surface, two double-ended boilers.	I. H. P. main engines per square foot of grate.	I. H. P. main engines per pound of oil per hour.	Square feet of heating surface, per I. H. P.	Pounds of oil per hour per I. H. P.	Pounds of oil per knot run.	Knots made per ton of oil.	Knots made per barrel of oil.	Slip of screw in per cent.	Actual time.		Remarks.
Tahiti to San Francisco.																		*h.*	*m.*	
August 1	298	12.6	65.3	2,172	240	34.3	3,222	258	8,302	8.42	.674	3.82	1.49	258	8.7	1.24	15.6	23	50	
August 2	323	13.6	70.1	2,490	280	40	3,774	258	8,302	9.65	.66	3.33	1.51	277.4	8.08	1.15	15	23	44	
August 3	322	13.6	70.1	2,646	280	40	3,772	258	8,302	10.24	.70	3.14	1.428	278.2	8.85	1.15	15	23	45	
August 4	334	14	71.3	2,785	290	41.43	3,954	258	8,302	10.8	.704	2.98	1.42	277.8	8.06	1.15	13	23	46	
August 5	357	15.04	72.4	2,892	305	43.57	4,111	258	8,302	11.21	.703	2.87	1.39	274	7.96	1.14	9	23	44	
August 6	346	14.6	71.9	2,772	310	44.3	4,177	258	8,302	10.8	.66	3	1.50	287	7.8	1.11	10	23	45	
August 7	322	13.5	71	2,777	310	44.3	4,177	258	8,302	10.7	.66	2.98	1.50	308	7.27	1.04	15.7	23	45	Strong head wind and sea.
August 8	343	14.4	71.9	2,936	315	45	4,207	258	8,302	11.38	.698	2.83	1.402	297	7.62	1.09	11.3	23	43	Wind and sea moderate ahead.
August 9	327	13.7	69.4	2,553	305	43.57	4,109	258	8,302	9.89	.621	3.212	1.606	295.4	7.272	1.07	12.6	23	45	
August 10	347	14.6	72.9	2,863	320	45.71	4,313	258	8,302	11.10	.663	2.90	1.507	295.1	7.60	1.084	11.7	23	44	
August 11	341.1	14.8	73.54	2,968	322	46	4,480	258	8,302	11.5	.663	2.79	1.51	302.8	7.407	1.06	12	23		
Total	3,660.1				3,277	468.14												260	31	
Average		14.05	70.91	2,770	302	43.18	4,026	258	8,302	10.73	.688	3	1.45	286.3	7.818	1.111	12.8			
Total knots	7,098.1				6,080															
Average, 2 runs	3,549	13.58	68.05	2,481	278.4	34.29	3,719	258	8,302	9.661	.665	3.393	1.503	273.6	8.201	1.165	12.97			
Average speed made during round trip.	325.7																			

The following summary of the second voyage of the steamship *Mariposa* on the round trip between San Francisco and Tahiti, as compared with the first trip, shows that the oil consumption on the second voyage was considerably less than that on the first, due to two causes: Improvements in detail of the oil-fuel installation and increased skill and intelligence upon the part of the engine-room force.

Oceanic Steamship Mariposa, voyage No. 2, from San Francisco to Tahiti, 1902.

Date.	Knots per day.	Knots per hour.	Revolutions per minute.	Oil used per day, in barrels.	Oil used per day, in tons of 2,240 pounds	Oil used per hour, in pounds	Pounds of oil per knot run.	Knots made per ton of oil.	Distance run per barrel of oil, in knots.	Slip of propeller, per cent.
August—										
21	328	13.3	63.7	255	36.43	3,400	248.8	9	1.29	7
22	297	12.3	62.6	225	32.14	3,000	242.8	9.24	1.32	13.4
23	282	13.3	64	210	30.00	2,800	237.4	9.43	1.35	9
24	330	13.6	65.9	235	33.59	3,133	227.9	9.82	1.40	8.8
25	310	12.8	62	220	31.43	2,933	227.1	9.86	1.41	8.8
26	311	12.8	62	210	30.09	2,800	216.1	10.37	1.48	8.5
27	292	12.1	62	220	31.43	2,933	241.1	9.29	1.33	13.8
28	305	12.6	62.1	220	31.43	2,933	230.8	9.70	1.39	10.3
29	305	12.6	62.2	220	31.43	2,933	230.8	9.70	1.39	10.5
30	322	13.3	65	230	32.86	3,066	228.6	9.80	1.40	9.5
31	326	13.5	66	240	34.28	3,200	235.6	9.51	1.35	9.4
Average, 11 days	309.9	12.96	63.4	226	32.28	3,013	233.3	9.60	1.37	9.9
Voyage 1, 11 days	312.7	13.12	65.2	254.8	36.40	3,412	260.9	8.585	1.22	13.14

Average temperature of uptake, 548°; average temperature of superheaters, 360°; average temperature of cold oil, 91°.

Oceanic Steamship Mariposa, voyage No. 2, from Tahiti to San Francisco, 1902.

Date.	Knots per day.	Knots per hour.	Revolutions per minute.	Oil used per day, in barrels.	Oil used per day, in tons of 2,240 pounds	Oil used per hour, in pounds	Pounds of oil per knot run.	Knots made per ton of oil.	Distance run per barrel of oil, in knots.	Slip of propeller, per cent.
September—										
6	292	12.2	62.1	215	30.71	2,867	235.6	9.51	1.36	12.6
7	301	12.6	62.6	220	31.43	2,933	233.8	9.57	1.37	11.2
8	288	12.1	62.9	220	31.43	2,933	244.4	9.16	1.31	15.5
9	298	12.5	63.1	220	31.43	2,933	236.2	9.48	1.35	12.6
10	276	12.2	64.7	220	31.43	2,933	255.1	8.46	1.25	13.4
11	327	13.7	66.9	245	35	3,267	240	9.34	1.33	9.4
12	303	12.7	67.1	250	35.71	3,333	264	8.48	1.21	16.5
13	317	13.2	67.3	265	37.44	3,533	267.5	8.53	1.20	13
14	307	13.2	67.4	260	37.45	3,466	271	8.20	1.18	13
15	324	13.8	69	265	37.94	3,533	261.7	8.54	1.22	12
16	321	13.5	69.2	270	38.57	3,600	269.1	8.32	1.19	13.9
Average, 11 days	304.9	12.7	65.7	241	34.46	3,212	252.6	8.87	1.27	13.01
Voyage 1, 10 days	331.9	13.96	70.6	295.5	42.22	3,981.6	284.79	7.841	1.122	12.89

Average temperature of uptake, 546°; average temperature of superheaters, 360°; average temperature of cold oil, 90°.

The Bureau has received from President John D. Spreckles, of the Oceanic Steamship Company, the general results secured on the seventeenth voyage of the steamship *Mariposa.* It will be observed that comparing this data with that of the first and second voyages a slight increase in efficiency has been secured. A study of the comparative results of the first, second, and seventeenth voyages will show that even on the first voyage an oil-fuel installation on marine vessels can be operated with a fair degree of success with a comparatively inexperienced crew.

Comparative performances Oceanic Steamship Mariposa, using oil as fuel.

OUTWARD TRIP.

Date.	Voyage No.	Knots per day.	Knots per hour.	Revolutions per minute.	Barrels oil per day.	Oil per day, in tons of 2,240 pounds.	Oil per hour, in pounds.	Pounds of oil per knot.	Knots per ton of oil.	Distance per barrel of oil, in knots.	Slip, per cent.	Average temperature, uptake (° F.).	Average temperature, superheater (° F.).
July, 1902	1	312.7	13.12	65.2	254.8	36.40	3,412	260.9	8.585	1.22	13.14	......	......
August, 1902	2	309.9	12.96	63.4	226	32.28	3,013	233.3	9.60	1.37	9.9	548	360
February, 1904	17	302.2	12.80	61	217	31	2,893	229.7	9.716	1.39	7.3	425	388

HOMEWARD TRIP.

Date.	Voyage No.	Knots per day.	Knots per hour.	Revolutions per minute.	Barrels oil per day.	Oil per day, in tons of 2,240 pounds.	Oil per hour, in pounds.	Pounds of oil per knot.	Knots per ton of oil.	Distance per barrel of oil, in knots.	Slip, per cent.	Average temperature, uptake (° F.).	Average temperature, superheater (° F.).
August, 1902	1	332.7	14.05	70.91	302.0	43.18	4,026	286.3	7.818	1.111	12.8	......	......
September, 1902	2	304.9	12.7	65.7	241	34.46	3,212	252.6	8.87	1.27	13.01	546	360
March, 1904	17	308.4	12.8	61.9	221	31.57	2,946.5	229.3	9.76	1.395	9.1	463	383

There has also been received from the administrative officials of the Oceanic Steamship Company the abstract of the steam log of twenty-three voyages of the steamship *Alameda*, a sister ship of the *Mariposa.* During eight of these voyages coal was used as a fuel. On seven of the trips the machinery was only in fair adjustment, and an inexperienced crew operated the oil-fuel plant. During eight other voyages with an oil fuel installation the machinery was in an excellent state of adjustment and operated by an efficient crew. A careful study of the data of this steamship will give some of the most reliable information as to the relative efficiency and economy of a coal and oil fuel plant on a merchant vessel.

Abstract of log of steamship Alameda, plying between San Francisco, Cal., and Honolulu, Hawaii, showing comparative performance between coal and oil.

COAL FUEL (MACHINERY ONLY IN FAIR ADJUSTMENT).

No. of the voyage.	Outward or homeward.	Length of voyage.		Main engines.			Vacuum, in inches.	Average distance made each day of 24 hours.	Fuel per day.		Air pressure for atomizing.	Gravity of oil, Baumé.	Burners in use.
				Pressures.									
		Days.	Hours.	Boiler.	First record.	Second record.			Coal, in tons.	Oil, in barrels.			
102	Outward........	6	9	175	......	......	25	323	71.04	....	......	......	......
102	Homeward	6	6	177	......	......	25	331	66.48	....	......	......	......
103	Outward........	6	1	175	......	......	25	343	68.88	....	......	......	......
103	Homeward	5	19	178	......	......	25	357	71.76	....	......	......	......
104	Outward........	6	2	175	......	......	25	340	67.68	....	......	......	......
104	Homeward	5	22	175	......	......	25	350	71.28	....	......	......	......
105	Outward........	5	19	175	......	......	25	356	73.92	....	......	......	......
105	Homeward	6	....	174	......	......	25	346	73.92	....	......	......	......
106	Outward........	6	1	164.5	......	......	25	343	64.80	....	......	......	......
106	Homeward	5	23	175	......	......	25	347	73.68	....	......	......	......
107	Outward........	6	5	154	......	......	25	348	68.88	....	......	......	......
107	Homeward	5	23	170	......	......	25	348	74.16	....	......	......	......
108	Outward........	5	23	171	......	......	25	349	69.12	....	......	......	......
108	Homeward	5	22	174	......	......	25	350	80.88	....	......	......	......
109	Outward........	6	4	163	......	......	25	339	68.64	....	......	......	......
109	Homeward	5	21	171	......	......	25	353	74.88	....	......	......	......
OIL FUEL (MACHINERY ONLY IN FAIR ADJUSTMENT, INEXPERIENCED MEN OPERATING BURNERS).													
113	Outward........	5	17	174.5	40.1	12.1	26	362	....	349	16.9	14.2	30
113	Homeward	5	20	175	48.7	14	27	356	....	388	14.5	14.4	30
114	Outward........	5	17	174	65.9	14.1	27	365	....	352	15	14.6	30
114	Homeward	6	....	175	76	17	26	348	....	391	16	14.5	30
115	Outward........	5	20	175	55	12	25	355	....	341	11	14.4	41
115	Homeward	5	21	175	62	15	25	350	....	379	14	14.2	35
116	Outward........	5	21	164	49	6	24	352	....	281	10	14.3	30
116	Homeward	6	2	175	64	8	24	343	....	344	13	14.3	36
117	Outward........	5	23	174	51	5	24	349	....	298	14	14	36
117	Homeward	5	23	175	56	7	24	348	....	343	12	13.8	42
118	Outward........	5	21	175	55	4	24	353	....	307	9	13.9	41
118	Homeward	5	22	175	58	6	24	350	....	319	10	13.6	42
119	Outward........	5	22	175	56	5	24	353	....	317	10	13.6	42
119	Homeward	5	23	175	62	6	24	348	....	331	10	13.8	42

Abstract of log of steamship Alameda, plying between San Francisco, Cal., and Honolulu, Hawaii, showing comparative performance between coal and oil.

COAL FUEL (MACHINERY ONLY IN FAIR ADJUSTMENT).

Temperature.							Percentage of ash in coal.	Remarks.
Injection.	Discharge.	Feed.	Engine room.	Fireroom.	Superheated air.	Base of smokestack.		
....	....	....	....	....	....	....	22.1	These eight voyages were made with coal as a fuel; with the ship having a new installation of boilers and engines. These runs cover a period during which the motive plant had not the opportunity to demonstrate its efficiency as when the machinery had reached its best working condition, as it probably did at a later date. The coal used was a mixture of the British Columbia and Australia production. Its evaporative efficiency under a test boiler (Scotch) was about 7.75 pounds of water per pound of fuel from and at 212° F. It will be observed that the percentage of ash was quite high. As the vessel experienced both favorable and unfavorable conditions as regards weather during these eight voyages, it may be presumed that the data furnished is sufficient in quantity to give average results. The actual distance traveled was 33,154 miles, and 6,878 tons of coal were consumed in the boilers of the ship. It therefore required 465 pounds of coal to drive the vessel 1 mile in distance.
....	....	....	....	....	....	....	17.5	
....	....	....	....	....	....	....	17.2	
....	....	....	....	....	....	....	17.1	
....	....	....	....	....	....	....	24.5	
....	....	....	....	....	....	....	20	
....	....	....	....	....	....	....	18.2	
....	....	....	....	....	....	....	19.4	
....	....	....	....	....	....	....	20.7	
....	....	....	....	....	....	....	18.9	
....	....	....	....	....	....	....	16.7	
....	....	....	....	....	....	....	21.6	
....	....	....	....	....	....	....	21.4	
....	....	....	....	....	....	....	17.1	
....	....	....	....	....	....	....	20.2	
....	....	....	....	....	....	....	23.9	

OIL FUEL (MACHINERY ONLY IN FAIR ADJUSTMENT, INEXPERIENCED MEN OPERATING BURNERS).

63	90	210	85	101	390	536	......	These were the first seven voyages made by the vessel where oil was used as a fuel. The crew were comparatively inexperienced in the operation of an oil-fuel plant, and therefore the best results were not secured. While making these seven round trips with crews practically inexperienced in the operations of the oil burners there was consumed for steaming purposes 28,183 barrels of oil. The distance made by the ship was 29,078 miles. In comparing this performance with the results secured when burning coal it will be noted that the relative efficiency of oil fuel and an inferior grade of coal was thus found, after extended test under conditions stated above, to be in the ratio of 1 to 1.42. This comparison is based upon the standpoint of weight. As a pound of oil costs less in San Francisco than a pound of any grade of coal suitable for marine purposes, the economy of using oil fuel in the steamship Alameda is thus clearly apparent.
63	95	210	82	94	390	635	......	
64	104	210	84	104	393	630	......	
63	100	205	81	91	385	608	......	
63	99	209	87	107	420	576	......	
63	101	208	77	97	405	557	......	
65	99	209	84	101	415	475	......	
66	100	201	83	99	396	444	......	
66	103	106	88	111	388	436	......	
68	105	208	85	110	383	453	......	
68	110	208	86	111	375	460	......	
71	110	208	92	112	377	593	......	
68	110	209	95	115	388	480	......	
68	110	208	90	100	391	443	......	

Abstract of log of steamship Alameda, plying between San Francisco, Cal., and Honolulu, Hawaii, showing comparative performance between coal and oil—Continued.

OIL FUEL (MACHINERY WELL ADJUSTED, BURNERS EFFICIENTLY OPERATED).

No. of the voyage.	Outward or homeward.	Length of voyage.		Main engines.				Average distance made each day of 24 hours.	Fuel per day.		Air pressure for atomizing.	Gravity of oil, Baumé.	Burners in use.
				Pressures.									
		Days.	Hours.	Boiler.	First record.	Second record.	Vacuum, in inches.		Coal, in tons.	Oil, in barrels.			
124	Outward........	5	21	175	51.8	4.8	25	358	....	300	9	13.9	45
124	Homeward......	5	18	175	53	5	25	362	....	314	9	13.2	45
125	Outward........	5	21	160	56	6	25	355	....	310	9	14	45
125	Homeward......	5	21	160	53	5	25	353	....	310	9	14.1	45
126	Outward........	5	20	175	52	5	25	353	....	307	9	13.9	45
126	Homeward......	5	21	171	51	4	25	355	....	281	9	13.4	45
127	Outward........	5	18	174	58	8	25	360	....	340	9	13.4	45
127	Homeward......	5	23	175	59	8	25	350	....	334	9	13.4	45
128	Outward........	5	20	175	50	4	25	355	....	298	8	13.9	45
128	Homeward......	6	6	175	59	7	25	331	....	355	8	13.8	45
129	Outward........	5	21	174	52	4	25	355	....	274	8	13.9	45
129	Homeward......	5	21	175	55	6	25	358	....	305	8	13.7	45
130	Outward........	5	20	175	55	6	25	355	....	312	8	14	45
130	Homeward......	5	21	175	53	6	25	353	....	307	8	13.4	45
131	Outward........	5	21	175	57	8	25	353	....	336	8	14	45
131	Homeward......	5	21	175	51	7	25	355	....	293	8	13.6	45

Abstract of log of steamship Alameda, plying between San Francisco, Cal., and Honolulu, Hawaii, showing comparative performance between coal and oil—Continued.

OIL FUEL (MACHINERY WELL ADJUSTED, BURNERS EFFICIENTLY OPERATED).

Temperature.							Percentage of ash in coal.	Remarks.
Injection.	Discharge.	Feed.	Engine room.	Fireroom.	Superheated air.	Base of smokestack.		
70	106	208	95	107	405	476	......	During these eight voyages the machinery department was in such a state of efficiency that the best possible results ought to have been secured. The crew had also become experienced in the operation of an oil-fuel plant. The results of these voyages may be compared with the performances of the Mariposa, bearing in mind that the Alameda runs on a faster schedule than her sister ship, the Mariposa. When burning a slightly refined California oil product with an experienced crew in the fireroom, and with machinery in good condition, there was consumed for steaming purposes during these eight round trips 29,363 barrels of oil. The distance made by the vessel on those voyages was 33,229 knots. There was, therefore, required 300 pounds of oil fuel to drive the ship a distance of 1 knot. The relative consumption of oil as compared with an inferior grade of coal is therefore in the ratio of 1 to 1.55. It will likewise be noted that not only was a more uniform pressure carried in the boilers with oil as a fuel, but that the average time required to make the voyage was reduced a few hours.
69	110	210	90	104	393	500	......	
69	109	210	93	113	410	465	......	
67	108	210	88	105	398	446	......	
67	109	210	93	109	405	456	......	
66	109	210	90	107	405	423	......	
66	107	211	90	104	408	457	......	
66	109	212	89	96	400	457	......	
66	108	212	93	108	393	408	......	
65	108	206	87	99	376	457	......	
64	108	212	88	104	395	423	......	
63	108	212	89	112	398	408	......	
64	107	212	91	107	383	408	......	
63	106	212	90	111	366	426	......	
65	105	212	87	102	358	435	......	
64	108	212	89	116	366	433	......	

THE OIL-FUEL INSTALLATION OF THE STEAMSHIPS NEVADAN AND NEBRASKAN.

The attention of the board had been specifically directed to the oil-fuel installation of the steamers *Nevadan* and *Nebraskan* of the American-Hawaiian Steamship Company. As the steamship *Nebraskan* of this line had made the voyage from New York to San Diego, California, with coal as a fuel, and had made the return trip from San Diego to New York with an oil-fuel installation, the board regarded it as of importance to inspect the installation of the vessel as early as possible after her arrival in New York.

Through the courtesy of Capt. W. D. Burnham, the manager of the line, the board made a personal examination of the installation of this vessel just after the arrival of the ship in port from San Diego, the vessel having made only one stop for a few hours at Sandy Point, Straits of Magellan, on the voyage from the Pacific coast.

The *Nebraskan* left New York August 7, 1902, touching at the ports of St. Lucia, British West Indies, and Coronel, Chile, for coal. She reached San Diego in fifty-seven days, five hours, and forty-three minutes. On that voyage 2,267 tons of coal of poor quality were used, and a fireroom crew of fifteen men was found necessary. The ship was kept at full speed during the entire voyage.

On the voyage from San Diego to New York, with a greater cargo in her hold, the voyage was completed in fifty-two days, seven hours, and twenty-six minutes. There were consumed in the furnaces on this voyage 8,826 barrels, or 1,260 tons, of California fuel oil. Only six men were required in the fireroom. Their wages approximated $50 per month each.

On the outward passage from New York to San Diego the ship steamed 13,280 miles, while on the homeward passage between San Diego and New York the ship steamed 12,760 miles, the increased distance on the outward passage being due to the fact that the ship called at both St. Lucia and Coronel for coal.

Four hundred and fifty-seven tons of measured space for cargo was saved by reason of the oil fuel being of less bulk. The resulting financial gain to the company from all causes was at the rate of $500 per day. While five days were saved on the eastward journey, it must be remembered that that voyage was 520 miles shorter.

The insurance risks, both on the vessel and on the cargo, were not increased with the installation of liquid-fuel appliances. The underwriters made careful examination of the arrangements for storing the oil fuel, as well as the general character of the oil-burning installation, and after special investigation regarded the equipment as one not constituting an element of danger sufficient to demand higher insurance rates.

In order to detect and collect any leakage of oil a cofferdam had been constructed both forward and aft of the principal fuel-oil bunker. At the end of the journey no leakage of oil had been observed. The oil used was from the California wells, a product which had undergone a light distillation, thus making it less explosive and less harmful to boiler and bunker plates.

In past years it had been observed that very injurious effects were produced upon the ends of boiler tubes and on the seams of plates with the use of crude petroleum as fuel. The experience of the superintending engineer of this line, Mr. Lassoe, is that when oil is slightly refined its use is less harmful than in the case of coal to all parts of the boiler, providing the liquid fuel is burned in a proper manner.

When firing boilers with coal as a fuel the firemen have necessarily to keep the furnace doors open a considerable time in order to secure efficient results. When the doors are opened for working a coal fire the cold air rushes in, and it is a fair estimate that the heat of the furnace during this time drops as much as several hundred degrees. With such extreme and rapid changes of temperature there must be a tendency of plates and even of tubes to contract, and attendant injury to the boiler often ensues. With the use of oil as a fuel it was found that the furnace doors did not need to be opened during the entire journey, and a more constant heat was thus obtained throughout the boiler. The full efficiency of the boiler is therefore more likely to be secured with the use of oil than with the use of coal as a fuel, and this has been evidenced in the steamers of this line by the more uniform pressures noted on the steam gauges.

The comparative results secured with coal and oil as a fuel by the *Nebraskan* when making long voyages are strikingly shown in the accompanying table. When making the first voyage to the Pacific coast, coal was used in the furnaces. On the return trip from the Pacific an oil-fuel installation was in operation. It will be noticed that the displacement of the vessel on these three long voyages was about the same, consequently the relative evaporative efficiency of the two kinds of oil, as well as of coal with oil, can be clearly established. While the coal used on the westward voyage was of an inferior grade, the hull of the ship was in much fouler condition on the voyage eastward, and these are factors that must be considered in determining comparative results.

Special attention is directed to the comparative data secured on the voyage from San Diego to New York, where California oil was used as a fuel, with the voyage between New York and San Francisco, where the Texas product was used as a combustible.

During the passage from New York to San Francisco, however, where the Texas product was used as a fuel, the vessel encountered very severe weather in the South Atlantic. Before entering the Straits of Magellan on this voyage the ship was almost hove to for two or three days.

The Howden draft system proved a decided advantage in the burning of the Texas as well as the California product. With this arrangement of utilizing the heat of the waste gases, no cold air is admitted to the furnace, thereby minimizing the fluctuation of temperatures in the boilers. On several occasions the temperature of the escaping gases at the base of the stack was as low as 375° F., which indicates that complete combustion took place in the proper places.

While the general information received from the officials of the American-Hawaiian Steamship Company concerning the performance of the *Nebraskan* is of exceeding value, it is essential for military-naval purposes that more data in regard to details of installation and operation of the machinery of these ships be supplied the Navy Department. The board therefore suggests that a commissioned officer be detailed to make the voyage between the Atlantic and Pacific coasts on one of these steamers. There is no doubt but that an observing officer would succeed in collecting information concerning the burning of fuel oil that would be of the utmost value to a more thorough and complete knowledge of the fuel question. The time may be nearer than now realized when the Navy Department may be called upon to suddenly equip auxiliary war vessels, if not fighting ships, with oil-burning devices. There would be a saving of both time and expense in effecting such installation by continuing the investigation of the fuel-oil problem along every line where new data might be procured.

Summary of passages of the American-Hawaiian steamship Nebraskan; also one voyage of the steamship Nevadan, a sister ship, of the same dimensions and engines.

		Using coal, New York to San Diego.	Using California oil fuel, San Diego, Cal., to New York.	Using Texas oil, New York to San Francisco.	Using California oil as fuel, San Francisco to Seattle.	Using California oil as fuel, San Francisco to Honolulu.	S. S. Nevadan, using oil as fuel, Kahului, Hawaiian Islands, to San Francisco.
Time of voyage	days	57	52	54	2	6	8
	hours	5	5	6	23	22	6
	minutes	43	3	42	13	43	10
Time under way	days	53	51	52	2	6	8
	hours	20	7	11	21	22	6
	minutes	20	26	27	19	28	10
Stoppages during voyage	days	3					
	hours	9	21	4	1		
	minutes	23	37	11	54	Pilot 15	
Total engine revolutions during entire voyage		5,393,430	5,455,060	5,545,780	319,525	820,880	907,610
Revolutions:							
Per mile		406.1	428.65	422.21	393.5	393	445.7
Per minute		69.5	73.83	73.39	76.83	82.18	76.3
Time out of dock	months	2	6	2			5
	days	22	3		9		
Draft of vessel:		Ft. in.	Ft. in.	Ft. in.	Ft. in.	Ft. in.	Ft. in.
Leaving port	forward	24 8	25 1	25 2	12 11	18 2	24 3
	aft	24 3	25 0	25 10	17 10	20 10	24 11
Arrival at port	forward	21 7	21 8	21 6	12 8	17 4	23 6
	aft	22 6	21 9	22 6	17 5	20 3	24 10
Mean draft:							
During voyage	forward	23 2½	23 4½	23 4	12 9½	17 9	23 10½
	aft	23 4½	23 4½	24 2	17 7½	20 6½	24 10½
Even keel		23 3½	23 4½	23 9	15 2½	19 1¾	24 1½
Displacement	tons	8,300	8,417	8,576	5,184	6,700	8,900
Distance run by ship	knots	13,280	12,726	13,135	812	2,088	2,036
Distance run by propeller	do	15,076	15,252.34	15,496	893	2,294	2,536.8

Summary of passages of the American-Hawaiian steamship Nebraskan, etc.—Continued.

	Using coal New York to San Diego.	Using California oil as fuel, San Diego, Cal., to New York.	Using Texas oil, New York to San Francisco.	Using California oil as fuel, San Francisco to Seattle.	Using California oil as fuel, San Francisco to Honolulu.	S. S. Nevadan, using oil as fuel, Kahului, Hawaiian Islands, to San Francisco.
Average speed of ship .... knots..	10.27	10.33	10.43	11.76	12.54	10.2
Average speed of propeller .... do....	11.66	12.38	12.30	12.9	13.78	12.75
Average slip .... per cent..	11.9	16.56	15.2	9.11	9	20
Indicated horsepower:						
Main engines	1,635	1,986	2,010	1,875	2,325	2,190
Auxiliaries (estimated)	210	210	210	175	200	200
Total	1,845	2,196	2,220	2,050	2,525	2,390
Fuel consumption:						
Main engines (coal) .... tons..	[a] 2,269	....	....	....	....	....
Main engines (oil) .... barrels..	....	7,982	8,771.26	372	1,289	1,400
Auxiliaries (oil) .... do....	....	844	916.40	94	111	140
Total (oil) .... do....	....	[b] 8,826 [b] 9,126	9,687.66	466	1,400	1,540
Per hour (coal) .... pounds..	[c] 3,773 [d] 4,091	....	....	....	....	....
Per hour (oil) .... barrels..	....	7.17	7.69	6.66	8.4	7.77
Per indicated horsepower (oil) .... pounds..	2	1.10	1.12	1.07	1.12	1.09
Miles per ton of coal .... Eureka.. Coronel..	6.16 5.53	....	....	....	....	....
Miles per barrel of oil	....	1.44	1.36	1.742	1.48	1.35
Air pressure, inches of water in fireroom	....	.8	.8 to .9	$\frac{5}{10}$ to $\frac{7}{10}$	.5	$1\frac{1}{10}$
Air pressure for atomizing .... pounds..	....	1.5	1.25	$1\frac{1}{4}$	1.2	$1\frac{3}{8}$
Temperature of oil in heater .... °F..	....	150	90	150–160	175	175
Temperature at base of stack .... do..	....	490–500	430–450	500	575	510
Kind of fuel used	Coal.	Cal. slight refined.	Texas residuum.	Cal. slight refined.	Cal. 15° Baumé	Cal. slight refined.
Gravity of oil	....	15° Baumé at 60° F.	22¼° Baumé at 60° F.	16° Baumé....	.9655=8.04 lbs. per gallon.	16.4° Baumé at 60° F.
Temperature of oil received on board .... °F..	....	90	42	100	80	94
Tons of fuel carried	2,267	....	....	....	....	1,260

[a] Eureka-Coronel. [b] Plus evaporator and detentions. [c] Eureka. [d] Coronel.

There are also shown the logs of two intermediate voyages of this vessel, one from San Francisco to Seattle and one from San Francisco to Honolulu. The performance of the ship when making these intermediate trips is introduced in order to establish the fact that practically uniform results are secured in marine installations when using oil as a fuel.

The log of the *Nevadan*, when studied in connection with her sister ship the *Nebraskan*, will show that similar and equal results have been obtained on the two vessels. The *Nevadan* has now traveled 70,000 miles with oil-burning appliances, and practically no repairs have been made to her boilers since the oil-fuel installation was introduced.

The percentage of slip of the screws on the outward voyage from New York to San Diego was 11.9, while the slip on the voyage from San Diego to New York averaged 16.56. This difference is explained by the fact that the steamer leaving New York on the outward passage had been in dry dock and had been painted immediately before sailing, while the ship had been four and one-half months in the water when sailing from San Diego, the greater part of that time having been spent in San Francisco Bay, fitting out for stowage of oil fuel in double-bottom tanks; also from the fact that the vessel experienced considerably more adverse currents on the homeward passage than the outward from New York. The weather conditions may also have had something to do with the question of the slip of the propellers. Considering the great length of the two voyages, and the extended period during which both fuels were continuously used, the comparative information obtained ought to be regarded as exceedingly reliable and valuable.

On the voyage of the *Nebraskan* to New York the ship had but little reserve of fresh water, since it was found difficult to obtain the required amount at San Diego. The vessel, therefore, on the voyage from the Pacific coast had to use her evaporator for forty-five days, while on the voyage from the Atlantic coast, with only a poor quality of coal in her bunkers, she left New York with a reserve of fresh water amounting to about 150 tons.

It was found that in addition to the cost in fuel of effecting sufficient evaporation to make up for the loss of fresh water, there was also a loss in steaming efficiency due to the priming of the evaporators. The scant complement detailed for firerooms made it almost impossible to keep close watch on the evaporators, and therefore at times, in rough weather, salt water was carried over from the evaporators. If it had not been that the ship had a reserve of fresh water in the compartments beneath the fire and engine rooms when starting from New York, the vessel would have used 50 tons more coal on her outward voyage to San Francisco.

The following list of auxiliaries gives the diameter, stroke, and number of cylinders, and the indicated horsepower for each, roughly estimated, and to which might be added that, as the auxiliaries use a great amount of steam, the indicated horsepower of these has been put at double the amount—210—so as to have only one average of indicated horsepower per hour for both main or auxiliary engines in the log summaries.

The miles per barrel of oil depend, of course, upon the displacement or weight propelled.

Classification.	Size of cylinders.	Cylinders.	Indicated horsepower.
	Inches.		
Steering engine	7 by 7	2	3
Dynamo engine	6½ by 5	1	8
Refrigerating engine	9 by 8	2	9
Circulating engine	6 by 6	2	16
Blowing engine	9 by 12	2	26
Fan engine	5 by 4	4	16
Feed pumps	8 by 5 by 10	4	16
Ballast pumps, pumping oil from double bottom	7 by 10¼ by 10	2	5
Brine pumps	6 by 5¾ by 6	2	3
Oil pumps, for burners	5¼ by 3½ by 6	2	2
Evaporator pump	3 by 3	2	1
Total indicated horsepower			105

As these auxiliaries use fully 30 pounds of steam per indicated horsepower, or more than double that of main engines, they have been estimated at 210, so as to have but one average of oil per indicated horsepower in summary of log.

A statement of the comparative engine-room complement when using coal and oil, is interesting as showing the considerably reduced force required for oil burning. It will be strikingly suggestive, however, that rather higher technical ability is required for the oil-fuel conditions. As tersely expressed by the managing director of the line, "With an oil-fuel installation there is required trained furnace men rather than old-time stokers, while the coal passer has disappeared altogether."

The engine-room complement of the steamship *Nebraskan* when using oil consisted of 1 chief engineer, 3 assistant engineers, 6 oilers, 3 furnace men, 3 wipers to assist furnace men, 1 deck engineer.

The regular watch when the ship was underway consisted of 1 engineer, 2 oilers, 1 furnace man, 1 wiper.

When using coal on the voyage from New York there were five men on a watch in the fireroom instead of two, as in the case with oil fuel.

While it is possible to do without the "wipers" in the fireroom, it has been considered safer to carry these extra men in the boiler room. There was always a probability of one of the three furnace men becoming incapacitated, and therefore the work would have been too onerous if the furnace men had ever been compelled to stand watch and watch. The "wiper" rendered efficient service in helping to look out for the compressors and various pumps, and as it requires some practice to efficiently operate the burners, the best interests of the company were subserved by having such a rate included in the complement of the fireroom force. As the pay of the "wiper" is about double that of a coal passer, the actual gain as regards the pay of the fireroom force when using oil and coal is more apparent than real.

As to the hull of the ship, it was observed that the slightly refined oil was rather a preservative of the steel, since the oil contained a small quantity of asphaltum. As sulphur and other corroding agents are sometimes contained in the coal, the oil is not at a disadvantage as respects corrosion of the hull plate.

In the oil-fuel installation of the *Nebraskan* the oil is pumped to a heating tank and brought to a temperature of 175° F. It is then forced at a pressure of 15 pounds to the atomizer, where it mixes with heated air, supplied at a pressure of 1¼ pounds. An exceedingly fine spray results, and in that manner it is burned.

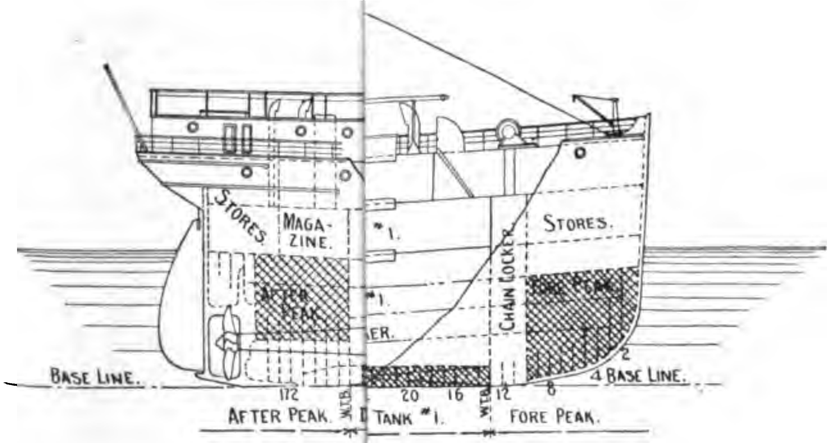
Every portion of the machinery operating the oil-burning installation is in duplicate. An irreparable breakdown is therefore almost impossible. On the return voyage to San Francisco the fuel supplied was from the Texas oil fields, and therefore the relative value of that oil can be compared as to thermal value and ease of operation with the California product.

An examination of the profile of the ship (fig. 38) will show that in vessels of such length there are but slight, if any, structural disadvantages to be encountered as regards stowing oil fuel as compared with the difficulties to be encountered in the case of armored cruisers and battle ships. In the case of naval construction the ship is of comparatively short length, and the construction of a bunker extending the full width of the ship and extending to the main deck would be a practical impossibility by reason of the installation of the protective deck as well as by the interference of various gun mountings and ammunition hoists.

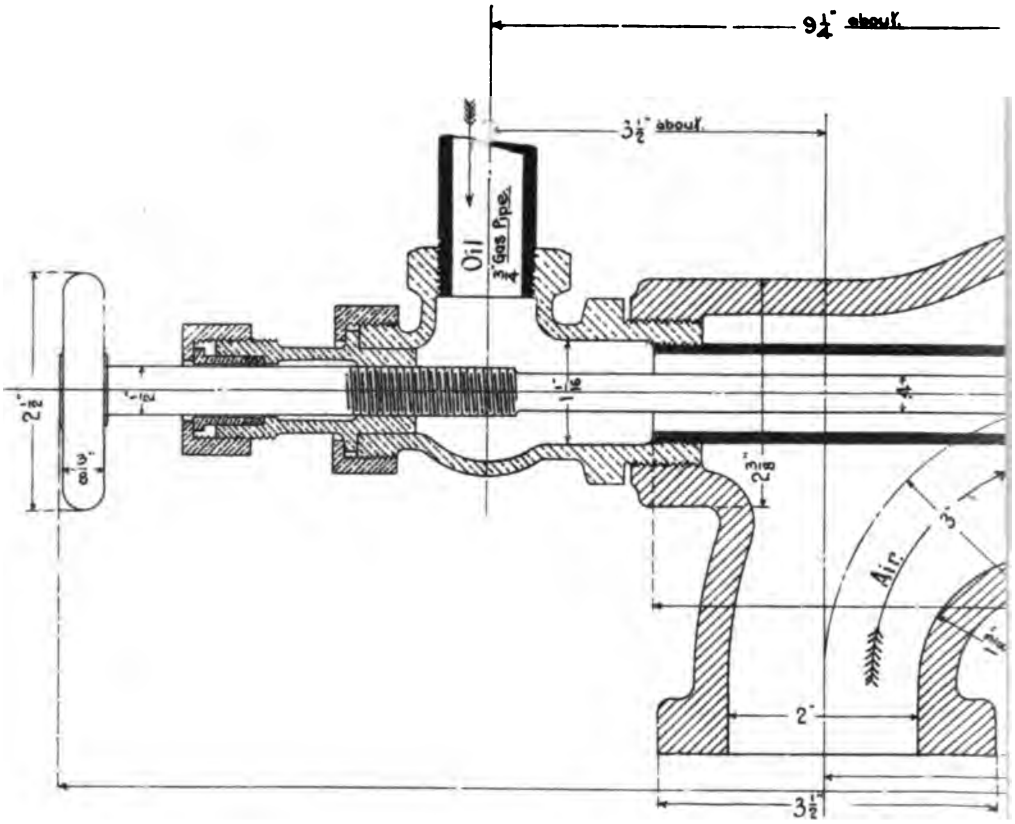
The special form of burner used on the *Nebraskan* was of the Lassoe-Lovekin type. Although this burner was not officially tested at the experimental plant, the board witnessed its operation, when used for auxiliary purposes, on this vessel.

This burner is a development of that shown in fig. 56, the latter burner having been used by the Standard Oil Company over twelve

e AVAILABLE OIL STORAGE



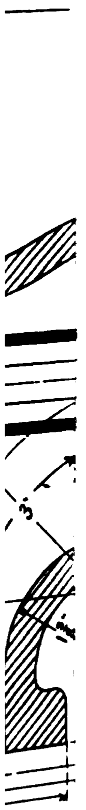
32196—04. (Faces page 302



9¼" about.
3½" about.
Oil
¾" Gas Pipe.
2½"
⅜"
½"
1 1/16"
4"
2⅜"
3"
Air
1½"
2"
3½"

years ago, the essential and distinctive feature of construction being the plug with radial holes fitted at the discharge end. It has been the improvement in the details of the installation of oil-fuel appliances rather than the discovery of any new principles that has caused in great part the satisfactory solution of the engineering or mechanical feature of the oil-fuel problem.

The general characteristics and construction of the burner are shown in the accompanying sketch (fig. 37). The marked feature of the appliance is the fitting of a plug at the discharge end of the burner, whereby the air is introduced into the furnace through a series of spiral holes rather than through a central orifice. The drilling of the numerous spiral holes in these plugs influences the length and character of the flame, and from the actual operation of the burners it can not be doubted that combustion is thereby effected near the front of the furnace rather than amid the tubes or within the smokestack. A range of experimentation on the details of this type of burner has already been indicated in figs. 29 to 34.



The distinguishing features of the general oil installation of the *Nebraskan* are as follows:

(*a*) Although the burner is so designed that either steam or air can be used as a spraying medium, air delivered under low pressure is preferred.

(*b*) The air necessary for supporting combustion is heated by means of the Howden system. A portion of this heated air is used for spraying purposes.

(*c*) The oil is heated so as to make it flow more readily through the pipe, and this heating of the fuel is effected by a steam coil fitted around the suction pipe of the oil pump.

(*d*) Special means have been provided to prevent any water that may enter the oil tanks from being pumped to the burners, a float arrangement having been installed whereby oil alone is pumped from the tanks.

(*e*) The brickwork installed in the furnace is of exceedingly simple character, the front end of the furnace being lined for about 2 feet, and a simple vertical lining against the back combustion wall being all the brickwork required.

(*f*) The main supply of fuel is carried in a bunker or expansion tank extending the full width of the ship, and for a distance of about 20 feet fore and aft carried from the bilge to the upper deck. There is a cofferdam both forward and aft of this oil bunker, and thus any leakage of oil can be quickly noted.

(*g*) There is a reserve of every important auxiliary, so that in case the impairment of one appliance occurs the reserve auxiliary can be immediately put in operation.

(*h*) When oil was first used in the Scotch boilers of the *Nebraskan* it was found that the smokestack temperatures reached as high as 1,800° F.

Retarders were then placed in the 3-inch tubes. The retarders now used have a convolution for each foot in length. The experience of this ship shows the exceedingly high velocity of the gases after complete combustion of oil fuel has been effected, and the imperative necessity of checking the flow of gases in all forms of boilers either by retarders or bafflers.

The whole design of the installation is of a character that represents excellent workmanship and generous attention to details. The heating of the air requisite for combustion, by the waste gases, undoubtedly increases the economical efficiency. There is a clear and distinct recognition of the fact that crude oil is a very dangerous fuel where there is careless or inefficient installation, and that the dangers of such an installation can be reduced to a minimum where the plant has been designed by experienced and conscientious experts, and operated by intelligent and observing engineers. The importance of guarding against any mixture of oil and water is shown by the precautions that have been taken to prevent any leakage in all steam and oil joints.

The general features of construction and arrangement of double-bottom tanks for the carrying of oil and water are as shown in fig. 38.

The general dimensions of the Nebraskan and its details are as follows:

Capacity of holds.

	Cubic feet.
Upper 'tween decks:	
Forward	38,570
Aft	33,510
'Tween decks:	
No. 1	15,335
No. 2	14,515
No. 3	13,180
No. 4	18,225
Holds:	
No. 1	29,890
No. 2	40,890
No. 3	22,556
No. 4	18,070
Refrigerators	23,489
Magazine	3,985
Total	272,215

General dimensions.

Length	360 feet.
Beam (molded)	46 feet.
Depth	34 feet.
Draft	23 feet.
Two engines	Twin screw.
I. H. P	3,000
Diameter of cylinders	19 inches, 31 inches, 54 inches.
Stroke	42 inches.
Two boilers	12 feet 3 inches by 16 feet 3 inches diameter.
Steam pressure	200 pounds.

Bunkers.	Cubic feet oil.	Tons coal.
Main bunker	24,460	525
Hatch trunk	620	14
Wing bunkers		432
Trunk and saddle back		18
Total	25,080	989

Oil in gallons	187,598
Oil in tons	641

Double-bottom capacity.

	Tons.
Inner bottom:	
No. 1	96
No. 2	196
No. 3	62
No. 4	48
No. 5	41
No. 6	86
No. 7	89
No. 8	35
Forepeak	139
After peak	84
Deep tanks (105–119)	178
Deep tanks (138–157)	148
Total	1,202

From the arrangement of the ship, as indicated in the longitudinal profile, it will be observed that the oil is stored in six separate compartments of the double bottom, and in the after peak and forward peak tanks, and in a large amidship-athwartship bunker. Under the engine and boiler compartment no oil is carried, but these compartments are reserved for the necessary supply of fresh water. Additional fresh-water tanks are installed just aft the engine room in side tanks located at the side of and above the refrigerator plant. There are also additional water tanks arranged in No. 4 hold between and at the sides of the shaft alley. These water tanks are sufficient to supply all the usual needs for fresh water. Any increase in the demand for fresh water can be made up by the evaporators.

The oil compartments in the double bottom are not directly contiguous to each other at the bulkhead subdivisions, and the necessary effect of a dividing cofferdam is obtained by the construction of the athwartship bilge well. Here any collection of gas or oil leaking from the tanks can be detected, thus affording an additional element of security. The large amidship oil bunker rises up to the upper 'tween decks, and is flanked on forward and after ends by cofferdams of one frame space in width, thus both ends of the bunker are readily accessible, and leaks of gas or oil can be checked in their incipiency. This large bunker is also provided with the usual division bulkheads or swash plates to prevent violent pitching of the oil during the rolling of the vessel. The expansion of the oil in this tank is taken care of by the construction of an expansion trunk reaching to the bridge deck.

Fig. 39 shows the general arrangement of the furnace installation of the oil fuel devices as fitted on the *Nebraskan*. It will be observed that the furnace is lined for its full length on the bottom while only for about half the distance on the top. There is a vertical brick lining to the back combustion wall to a distance just slightly higher than that of the height of the furnace.

Boiler data steamship Nebraskan (two single-ended Scotch).

Diameter	16 feet 3 inches.
Length	11 feet 6 inches.
Tubes between tube plates	8 feet 3 inches.
4 furnaces, Morison:	
Large D	3 feet $7\frac{1}{8}$ inches.
Small D	3 feet 3 inches.
3-inch tubes-common, 1 boiler, No. 12, B. W. G	196, total number.
3 tubes-stay, No. 3, B. W. G	110, total number.
Grate length	6 feet.
Grate surface, 1 boiler	81 square feet.
Tube surface, 1 boiler	2,527 square feet.
Heating surface, 1 boiler	178.5 square feet.
Total heating surface	2,998.5 square feet.
Steam capacity	495 cubic feet.
Area through tubes	15 square feet.
H. S.÷G. S	37.
G. S.÷area through tubes	5.29.
Shell plates	$1\frac{3}{8}$ inches.
Front and back	$1\frac{7}{32}$ inches.
Tube plate	$\frac{3}{4}$ inch.
Furnace thickness	$\frac{9}{16}$ inch.

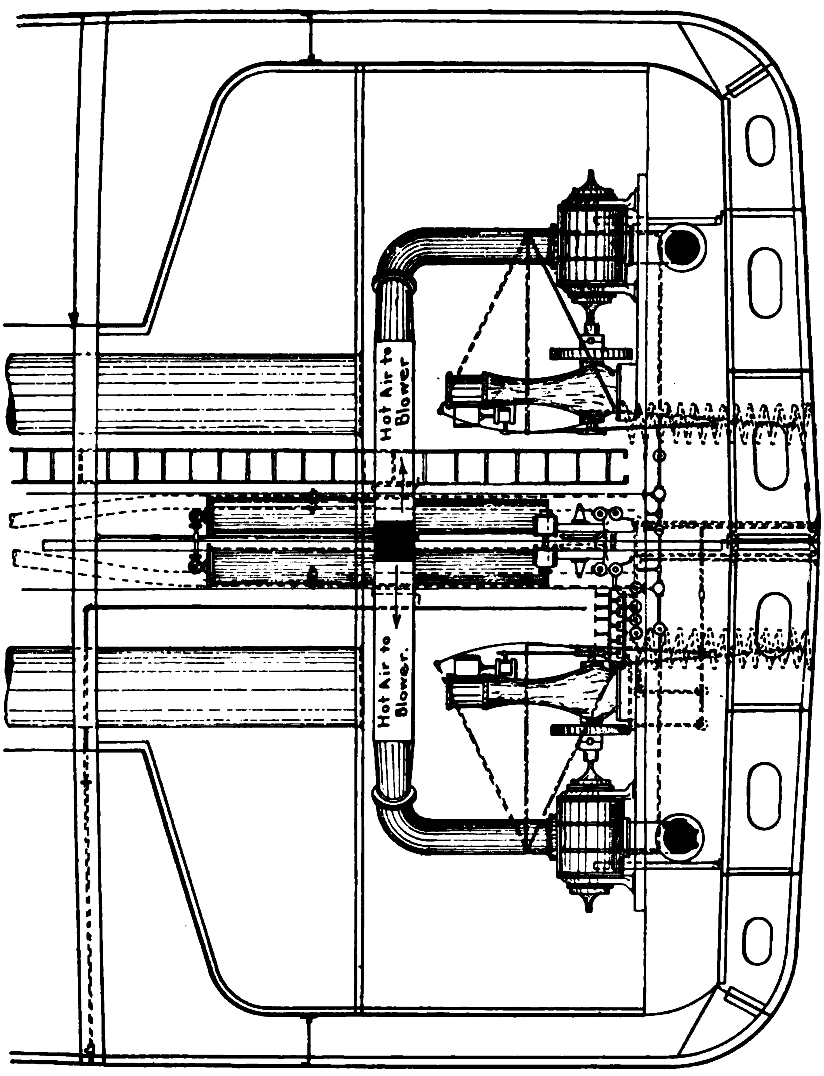


FIG. 40.—Thwartship section through furnace room, American Hawaiian Line S. S. *Nebraskan.*

SIMILARITY OF CONDITIONS ATTENDING THE OIL-FUEL INSTALLATIONS FOR LOCOMOTIVE AND TORPEDO-BOAT WORK.

OBSERVATIONS OF THE BOARD AT THE HOOSAC TUNNEL.

The progressive increase in the number of oil-fuel installations for locomotive work particularly interested the Bureau of Steam Engineering, and through the courtesy of the officials of the Atchison, Topeka and Santa Fe, and of the Boston and Maine railroads, reliable and valuable data and important drawings concerning such installations were placed at the disposal of the board.

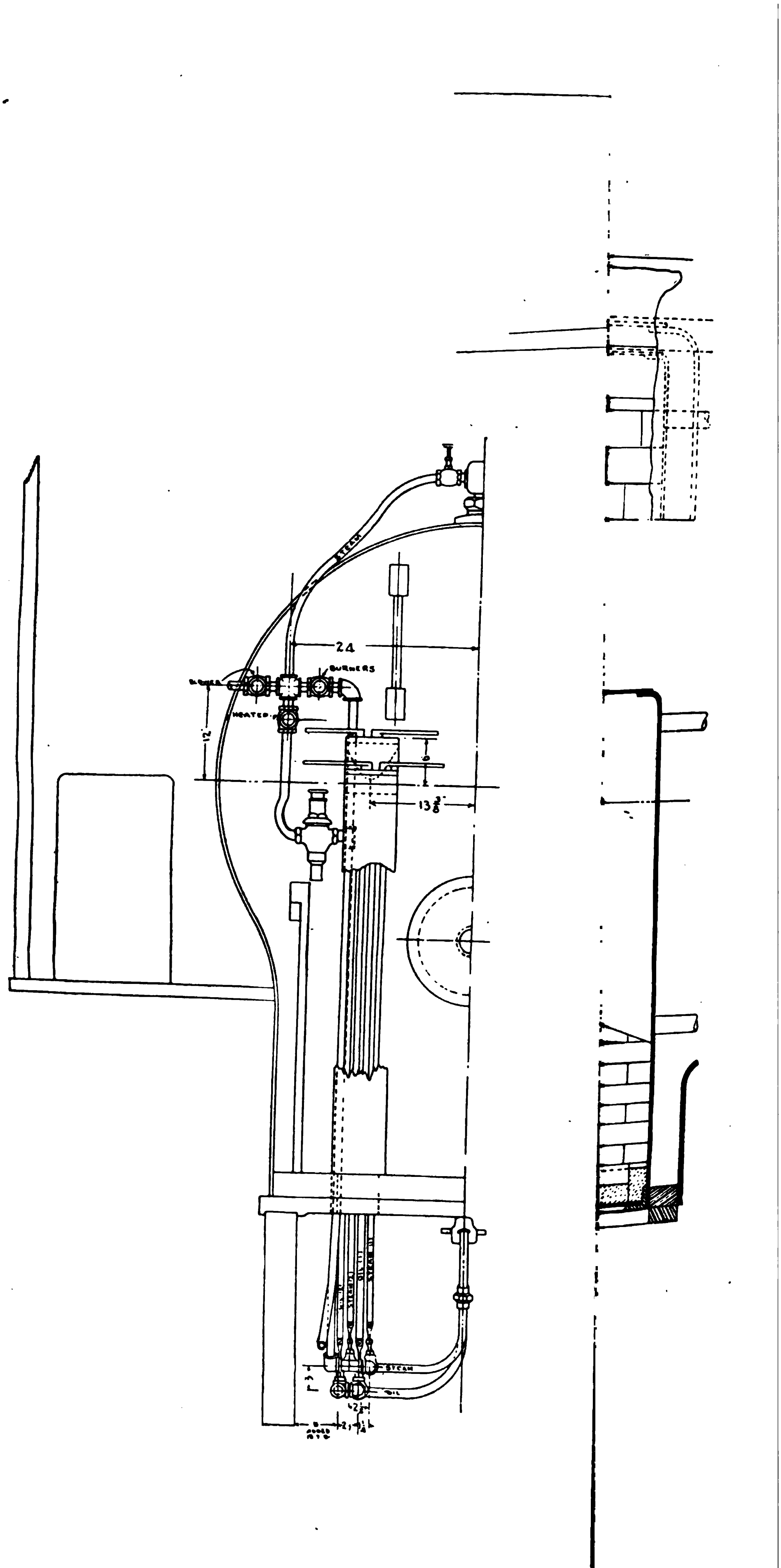
A special visit was made to the Hoosac Tunnel, where the application of oil fuel to four of the locomotives of the Boston and Maine Railroad had been effected. Oil-burning locomotives had been used there in order to keep the tunnel clear of the smoke that issued from the stacks when the coal burners were put to severe work while traversing the tunnel.

The Hoosac Tunnel is 4¾ miles long, and there is a grade each way within the tunnel of 26 feet to the mile. Until oil-burning helping locomotives were attached to each train it was impossible to keep the tunnel clear of smoke and steam. Therefore in the oil-fuel installation of these four locomotives it was essential to effect complete combustion, so that there would be practically no smoke issuing from the stack, a desideratum that is of great importance in railroad tunnel work.

The board, accompanied by Lieut. John Halligan, jr., U. S. Navy, not only rode back and forth through the tunnel on an oil-burning locomotive, but carefully inspected the entire equipment of the plant, special attention being given to the question of storage and supply.

For special information in regard to the Hoosac Tunnel oil-fuel locomotives, as well as to other railroad installations, the board is indebted to W. D. Hoffman, the fuel-oil expert of the Standard Oil Company. This expert has likewise been in charge of the work of installing liquid-fuel appliances on locomotives in Florida, as well as in other sections of the country, and the board is under obligations to him for valuable suggestions in regard to effecting such installations on torpedo boats.

The most important change made in the Hoosac Tunnel locomotives for burning oil instead of coal was in the fire-box arrangement. The drawing of the fire box shows the arrangement of the burner and the fire-brick arch (fig. 41). As may be seen, the burner enters the fire box just beneath the rear water leg and is inclined upward at an angle of 15°, so as to direct the flame under the arch. The ash pan is replaced by a special pan, which is bolted to the lower ring of the water leg, and supports the fire-brick lining and arch, as well as the



32196—04. (Faces page 309.)

dampers. The fire brick is laid up in alternate courses of headers and stretchers, although in front a single course of stretchers may be used, except in the center wall, which braces the arch to the tube sheet. At the back end of the box a tie wall is built in, resting on angle irons, to stay the side walls. The damper is arranged so that it may be entirely closed for holding the steam pressure with a light fire.

The burner is of ingenious construction, consisting of a double burner—a narrow one on top and a wide one below Both are flat, or slot, burners, with the steam orifice arranged behind that for the oil, so as to blow steam through the stream of oil. A burner of this type, with properly proportioned steam slot and opening for the atomized spray, like the one shown in fig. 41, attached to the locomotive, is capable of efficiently burning 150 gallons of oil per hour. A similar burner for locomotive work is shown in fig. 42, this burner being arranged for insertion in the fire door instead of at the mud ring. A large air opening is provided near the burner, to admit air for initial combustion, while the damper at the rear of the box furnishes what more is necessary. This burner has given satisfaction, having never become stopped up. With the small burner it is possible to adjust the fire very low for the purpose of holding steam during long waits or delays, while with both burners a capacity beyond any possible requirement is available.

The arrangement of the steam and oil piping for the burner is very simple. Oil is fed directly from the tender tank to the burners under 5 to 10 pounds air pressure (from brake reservoir), and the steam is likewise controlled by throttle valves, all of which valves have their handles located conveniently in the cab. The piping is, as shown, conveniently fitted with brass unions, to facilitate taking the burner down, and bends are used in place of fittings wherever possible. A steam connection is run to the tender, through a reducing valve, to supply the tank heater, and another steam connection is arranged outside the cab to supply the steam oil pump at the storage station when filling the tender tank.

In regard to the similarity of conditions and requirements of oil-fuel installations for locomotive and torpedo-boat work, the following advantages are practically obtainable in both cases:

(*a*) Economy of space reserved for carrying fuel.

(*b*) Ease in filling tanks.

(*c*) Rapidity of time in meeting a varying load on boiler.

(*d*) Ability to force boiler to extreme duty in case of emergency.

(*e*) Absence of smoke under light normal working conditions.

(*f*) Short height of stack.

(*g*) Superior personnel available for the operation of the burners.

(*h*) Ability to secure and maintain higher speed with oil fuel than with coal.

The accompanying photograph (fig. 43) showing one of the Boston and Maine engines "double-heading" just before entering the Hoosac tunnel, with oil and coal burning locomotives, will tell of the possibility of torpedo boats at reduced speed burning oil without smoke issuing from their stacks. It must be understood, however, that the smokeless burning of oil fuel in a torpedo boat can at present be effected only when there is a limited consumption of fuel. The efficiency of such boats, however, may be vastly increased when improved baffling is secured, and it is hoped that the smokeless burning of oil may be eventually obtained even with a marked increase in fuel consumption.

The board considers that the eradication or mitigation of the smoke nuisance in torpedo boats is intimately connected with the question of baffling, and the commanders of the various torpedo boat flotillas could render the Bureau an inestimable service by making experiments with various forms of baffling. In the small or bent-tube type of water-tube boilers the most important problem now confronting experts is a systematic arrangement of baffling whereby combustion can be effected within the tubes instead of within the smokestack. A special design of baffling will have to be arranged for each distinct type of water-tube boiler.

The appended photograph (fig. 44) of the U. S. torpedo boat *Gwin*, fitted with a "W. N. Best" design of installation, while undergoing some oil-fuel, dock trials at the Norfolk Navy-Yard, shows the success attained in the smokeless burning of liquid fuel. The evaporative capacity of the boilers obtained under these conditions was not great, but the board believes that with further investigation and experiment more satisfactory results as regards evaporative output will be secured.

The comparative study of oil-fuel installations for torpedo boats in connection with the development of locomotive oil burning is worthy of special and further investigation by the Department, and the good of the service would be subserved by detailing some of the commanders of the torpedo boats to special temporary duty in observing and reporting upon the work performed by the oil-burning locomotives of the Atchison, Topeka and Santa Fe and Southern Pacific Railroad systems.

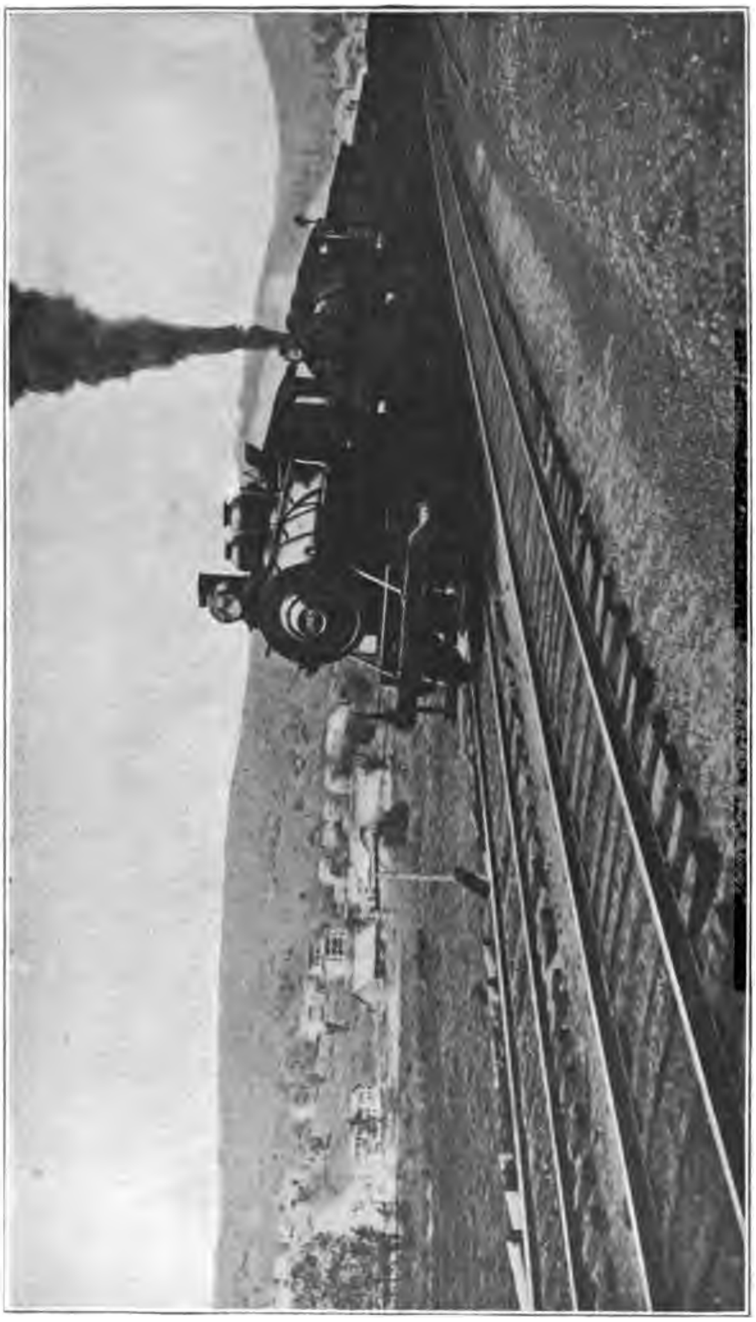


FIG. 43.—Oil and coal burning locomotives double-heading at Hoosac Tunnel.

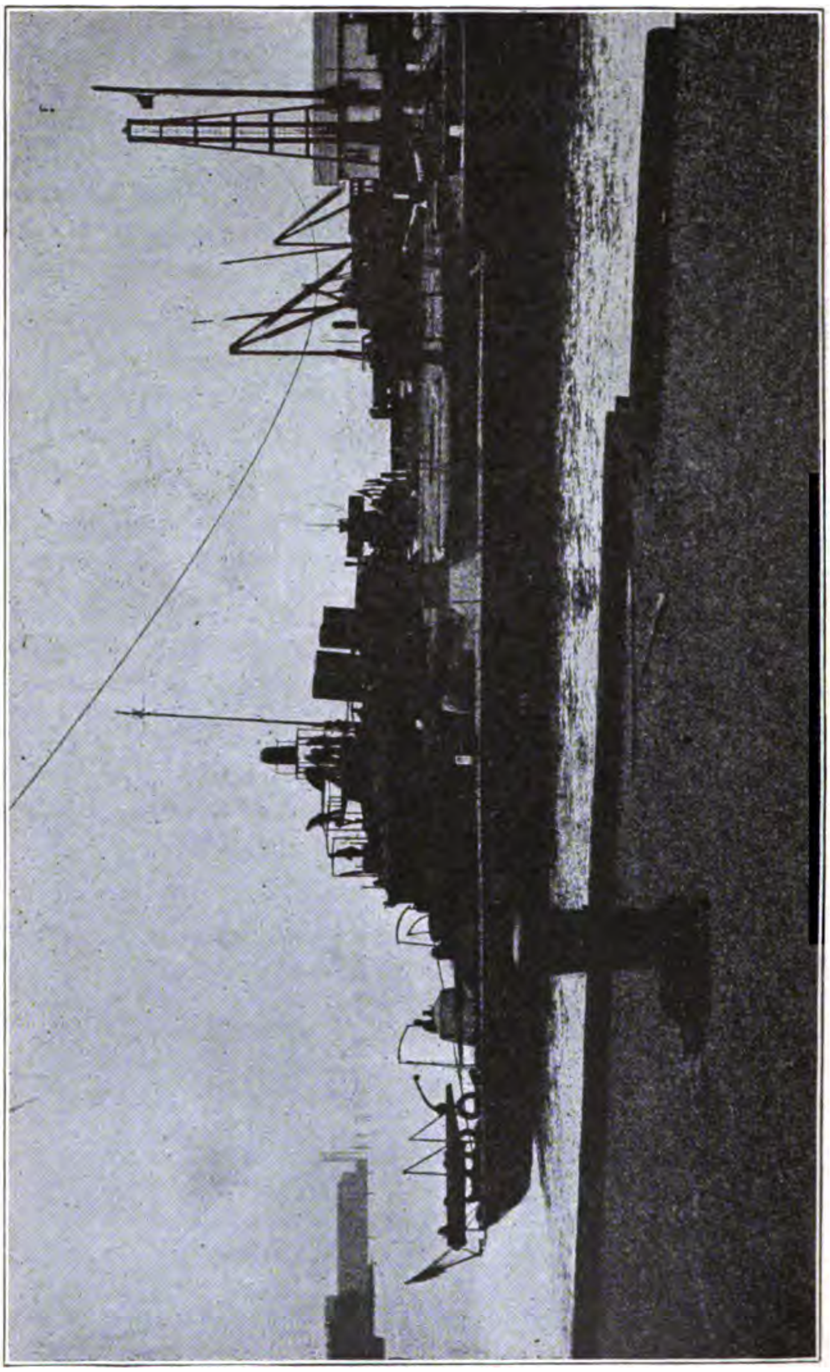


FIG. 44.—Dock test of the United States torpedo boat *Gwin*.

MECHANICS OF COMBUSTION AS SPECIALLY RELATING TO USING LIQUID FUEL.

While the theory of combustion is well understood by all having a knowledge of the elementary principles of chemistry, there are practical considerations that enter into the matter of burning both oil and coal as a fuel, and therefore the economical consumption of fuel in large quantities can only be effected in boiler or furnace installations which have been designed by technically trained experts possessing a knowledge of what well may be termed the practical mechanics of combustion. Considering also the widespread and special interest now taken in the oil-fuel problem and the fact that radically different systems of oil-fuel installations are being projected, it is deemed specially important to consider the question of how the combustion of oil may be best obtained.

Hundreds of oil burners have been designed which, viewed from a chemical and theoretical standpoint, should have operated efficiently; and yet when such appliances were subjected to actual tests the devices proved unsatisfactory. There are, therefore, practical conditions as well as chemical principles that must be considered in the solution of the liquid-fuel problem, and the board thus regards the mechanical features of the oil-fuel combustion question as a subject deserving of special study and investigation.

Everyone is aware of the fact that with a charcoal or coke fire it is possible to maintain very intense combustion within a comparatively small space and with very little smoke. This sort of fire was known to the smelters of the bronze age, and it is still used in blast-furnace and other operations where great concentration is required.

The explanation lies in the fact that the fuel is solid, even at the highest temperature. The solid particles in the smoke are probably particles of ash, but whether they are ash or unconsumed carbon, they are exceedingly small, as shown by the bright blue color of the smoke. As a result of this solidity no carbon can leave the bed of hot coals except as a constituent of CO or of CO_2. In either case the combustion will be free of soot or smoke, since both gases are colorless and transparent. If the carbon goes up the stack as a constituent of CO it carries with it two-thirds of the heat that it was primarily capable of yielding up, and it is only with respect to the possible formation of CO instead of CO_2 that a charcoal fire fails to give perfect results. Were it not for this possibility there would be no reason why a charcoal fire should need more space than is sufficient to contain the fuel itself.

The obvious way to prevent the formation of CO is to force a larger quantity of air through the bed of coals, but this alone is insufficient. Experience shows that even when the amount of oxygen passing through the bed of coals is twice that requisite for the complete combustion of the carbon, there is still some of the carbon that leaves the furnace in a partly burned condition. The only way in which this carbon can be completely burned is by subsequent diffusion of the gases whereby each molecule of CO sooner or later meets with an atom of free oxygen and so becomes CO_2. But this diffusion requires time; and as the gases are being constantly cooled as they are carried along, it may happen that they will be cooled below the ignition temperature before union takes place. So that even in a charcoal fire the need for appreciable combustion space is obvious.

Complete combustion requires that for every atom of carbon and for every two atoms of hydrogen there shall be at least one atom of oxygen brought in close proximity and then and there subjected to a temperature sufficient for ignition. In other words there must be a thorough mixture and then ignition. It is doubtful if a mere mechanical mixture, however complete, could ever be perfect enough to bring about the desired result. This is well illustrated by contrasting the smoky combustion of black gunpowder, where we have a mechanical mixture, with the combustion of the so-called smokeless powders, in which the mixture is so thorough and minute that similar proportions of oxygen, carbon, and hydrogen occur in each separate molecule.

In all ordinary cases of combustion, however, where we draw our supply of oxygen from the atmosphere, it is only by virtue of the property of diffusion that a sufficiently intimate mixture is attained. As to the real nature of diffusion, it is known that at ordinary temperatures the particles of oxygen in the air are moving about in every conceivable direction at velocities averaging over 1,600 feet per second. Any one atom, however, moves only an inappreciable distance before being arrested by collision with another atom. So that although the average velocity of the atoms is probably equal to that of a rifle ball, it still takes an appreciable time for a particle to travel even a moderate distance. It is this time element that constitutes the great stumbling block when the attempt is made to burn a large amount of combustible in a small space.

As before noted, the reason why intense combustion is easily attained with a charcoal fire is that the fuel is solid at the temperature of ignition. Being solid it can present a large surface for the oxygen to act upon, and an atom cannot break away and go up the chimney without first being united with at least one atom of oxygen.

In the combustion of hydrocarbons, on the other hand, we have the following conditions: The fuel is already on its way to the chimney before it is even partially burned. The first effect of the heat is to disassociate the carbon from the hydrogen. Whether or not the latter unites with the oxygen does not affect the soot or smoke question, since the constituents and also the products of combustion of hydrogen are alike transparent colorless gases. But in any case the carbon, left alone in the form of an impalpable dust, is much less favorably circumstanced than that in a charcoal fire. If it were attached to a hot coal, as in the charcoal fire, so as to be capable of receiving a blast of air, its combustion would be easily accomplished. But instead of this, it is carried along by the current of gases, and unless it is given plenty of time before being cooled it will be left alone as a particle of soot.

An examination of the nature of flaming leads to similar conclusions. The luminous part of a flame is caused by the white-hot particles of carbon. These particles have been robbed of the hydrogen with which they were formerly associated, and they have not yet met the oxygen necessary for complete combustion. This process of finding, or of being found by, the oxygen requires time, and if perchance the temperature falls below that of ignition before the process is completed, the carbon will be deposited as soot or else go on up the stack as smoke along with the excess of oxygen with which it should have been united. Thus an unmistakable symbol of the conditions that are necessary in order to burn a large amount of combustible in a small space is a short flame.

The circumstances which conduce to shortness of flame are:

First. Pure carbon fuel, because the fuel can not leave the grate or furnace until it is burned to CO at least. In any case it can not deposit soot, since CO when cooled is a transparent gas.

Second. Intimate initial mixture of oxygen with the fuel, since the more intimate the mechanical mixture the less time will it take the gases by the process of diffusion to become perfectly mixed.

Third. Initial heating of the air, since the rate of diffusion increases with temperature.

Fourth. Large surface of fuel presented for impact of the oxygen.

The desirability of supplying a combustion chamber whose volume is at least equal to the volume of the flames seems obvious. In this connection the fact should not be overlooked that a slight increase in the volume of the combustion space acts in two ways to improve the quality of the combustion. One way—that having to do with the greater time permitted for diffusion—has already been touched upon; but apart from that there are influences at work in consequence of which an increase in the volume of the combustion space actually diminishes the volume of the flames. This is because the temperature of the larger space is higher, and the higher temperature hastens the process of diffusion.

During the process of diffusion heat is being liberated at all points throughout the combustion space. Hence all parts of the space are being traversed by heat rays emanating from every other part of the combustion chamber. It is readily seen that the temperature within this space must, under these conditions, increase with the volume to an extent limited only by the transparency to radiant heat, and by the temperature of disassociation at which, necessarily, heat ceases to be liberated. Since the transparency of the combustion space is diminished by the presence of solid carbon (for whether black or incandescent it is in any case opaque), it follows that the increase of temperature with a given increase of volume will be less in a space filled with luminous flame than in one filled with burning hydrogen or CO.

This question of the proper size of the combustion space is further complicated by the presence and condition of the solid walls of the furnace, whether, for instance, they are themselves incandescent or merely black absorbers of heat. There seems no reasonable doubt, however, that incandescent walls will hasten diffusion and hence shorten flame.

Where it is possible for the diffusion to be completed before combustion begins as in the Bunsen gas burner the difficulties naturally disappear and there is readily attained a very short flame which, moreover, is incapable of depositing soot even on a cold object.

In the case of a liquid fuel which is incapable of vaporization the diffusion and ignition must occur simultaneously. With such a fuel there is bound to be considerable flaming. Another difficulty, and one from which all solid fuels are free, arises with this sort of fuel from the action of capilarity or surface tension. Thus, no matter how finely the liquid is pulverized, each tiny drop assumes a spherical shape and so presents the least possible surface for the impact of oxygen atoms.

From what has been said it seems clear that a liquid fuel such as crude petroleum requires an ample combustion space, more indeed than does almost any other sort of combustible material.

The relative dimensions—length, breadth, and depth—of the combustion space are of minor importance. The primary requisite is volume, and that alone, provided all parts of it are traversed by the same quantity of gas in a given time; in other words, provided the gases are not short-circuited through or across some parts of the space to the neglect of others. Thus, if a current of gas flows through a cubic foot of space at the rate of 1 cubic foot per second, each particle of gas will spend one second within the space, regardless of whether the space is long and narrow or short and wide. In a long and narrow space there is less chance of the gases taking a short cut, and herein lies the sole utility of introducing baffles in the combustion space. Indeed, there is a strong objection to their introduction arising from the fact that the narrower the passage the greater will be the velocity of flow and the greater the distance to be traversed. Since the resistance that the draft pressure must overcome is proportional to the square of the velocity of flow and to the length of the passage, it follows that for a given volume of combustion space the draft resistance will be proportional to the cube of its length. The advantages are, therefore, in favor of the combustion space of large cross section and short in the direction of the flow of the gases.

As to the difficulty arising from the tendency of the gases to follow the path of least resistance and to flow, for instance, with too great velocity at the center of the space and too little at the sides, that can always be checked by means of retarders placed so as to equalize the velocity over the cross section of the current. The difficulty, therefore, reduces itself to the mere trouble of finding out where to place the retarders, and this is obviously a question to be settled by experiment. What is true in this matter of the combustion space is also largely true of the tube space. The process of diffusion, so important to combustion, continues after the combustion is complete, and must have a good deal to do with the rate at which heat is abstracted from the gases by the heating surfaces. As affecting the necessary amount of draft pressure, a tube space short in the direction of flow of the gases and of large cross-sectional area is better than one of small area and long in the direction of flow; but on account of the lesser velocity of flow through the short space the gases within it will be less thoroughly mixed by eddying, and the importance of arranging the heating surfaces so as to permeate all parts of the space will be increased.

A primary requisite for the successful burning of a nonvolatile liquid fuel is the exposure of the fuel to the heat of the furnace in such a form that it presents the largest possible surface for the impact of the atoms of oxygen. From the principles of capillary action it is possible to establish a standard by which to judge of the efficiency of the various methods for increasing the free surface of the oil.

Oil in bulk has practically no surface. When broken up into fine drops, the surface is the aggregate surface of all of the drops. The smaller the drops of oil the more perfect the spheres. Thus drops of oil one one-thousandth of an inch in diameter are known to assume the spherical form with a rigidity comparable to that of a steel ball 1 inch in diameter. The work necessarily performed by the atomizing agent is simply the work of stretching the surface.

Petroleum whose density is 0.92 has a bulk of 30 cubic inches per pound. When broken up into spherical drops the surface of a pound of oil is $180 \div d$ square inches, d being the diameter of the drops expressed as a fraction of an inch. The work required to stretch the surface of petroleum is 0.0000151 foot-pound per square inch. From these facts we can compute the work done against surface tension in forming spray. This work is $0.00272 \div d$ foot-pounds per pound of oil. Thus for drops 0.0001 inch in diameter the work is 27.2 foot-pounds per pound of oil. There is no known method whereby, even in theory, oil can be sprayed with such a high degree of efficiency as that indicated above.

The only obvious way of stretching the surface of a liquid which, like petroleum, is incapable of being drawn into a thin film is by opposing force to change the momentum, and this necessitates imparting to each particle a velocity, and hence a kinetic energy.

The diameter of a gravity drop of oil (a drop which is broken off from a larger mass by the force of the weight of the drop itself) is about 0.15 inch. Starting from this datum we can derive an expression connecting the diameter of the drop with, for example, the diameter and the number of revolutions of a circular disk from the periphery of which the drops are thrown off by the action of centrifugal force. Such an expression is

$$n^2Dd = 10{,}570$$

where n = revolutions per minute,
D = diameter of disk in inches,
d = diameter of drop in inches.

The drops are, of course, thrown off with a velocity equal to the peripheral velocity of the disk. The kinetic energy represented by this velocity for petroleum, having the assumed density of 0.92, will be $0.00311\frac{D}{d}$ foot-pound per pound of oil.

This kinetic energy added to the energy required to stretch the surface of the oil gives us $\frac{0.00272 + 0.00311\,D}{d}$ foot-pound per pound of oil as the total energy required to spray the oil by this method. The kinetic energy is $1.14\,D$ times the energy required to overcome the surface tension. To illustrate the above, suppose the drops are 0.0001 inch in diameter and the disk is 8 inches in diameter. The work of stretching the surface will then be 27.2 foot-pounds and the kinetic energy will be 248.8 foot-pounds, making a total of 276 foot-pounds per pound of oil. Contrast this with the results attained with a steam jet.

When the oil is sprayed by a steam jet one-half pound of steam per pound of oil, or 5 per cent, of all the steam generated (evaporation 10 pounds of steam per pound of oil) is considered fairly economical. But in a moderately economical steam engine—i. e., one giving a horse-power for 34½ pounds of steam per hour—one-half pound of steam yields 28,700 foot-pounds, which, at 252 foot-pounds per pound of oil, is capable of spraying 104 pounds of oil into drops 0.0001 inch in diameter. The steam jet is therefore only about 1 per cent as efficient as is theoretically possible.

In making this comparison we have of course assumed that the steam jet also produces drops 0.0001 inch in diameter. More likely the steam jet produces drops of various diameters. Some idea of their probable size may be formed from the following dimensions:

0.00000045 inch, thickness of black spot in soap bubble.
.0000845 inch, thickest red of soap-bubble film.
.0001667 inch, } diameter of drops in cloud of exhaust steam from
.0002 inch, } low-pressure engine.
.00897 inch, }
.0222 inch, } diameter of drops in rain cloud just about to fall.

The development of a simple mechanical burner ought therefore to be not only possible but probable. For marine work particularly such a burner would possess advantages over any appliance that required air or steam for effecting atomization of the oil fuel.

A study of the liquid-fuel problem from the standpoint of the practical or mechanical rather than the theoretical or chemical feature of combustion would therefore show that when an assured and reasonably cheap supply of such fuel can be obtained, and when steam generators are designed for burning oil exclusively, it will be essential for the efficient and forced burning of such fuel to provide boilers of greater volume than now constructed for designated horsepowers.

The resulting gain from the installation of naval boilers of greater volume than now permitted for designated horsepowers (even though such boilers would require more weight and space than now allowed for such horsepowers) would subserve naval interests and be manifest in the higher efficiency, increased capacity, and in greater endurance of the boiler—the lungs of the vessel.

Where there are no limitations as to space, weight, or height, as in land boilers, the increase in volume could be best secured, in the case of fire-tube boilers, by lengthening the tubes and furnaces and by enlarging the combustion chambers.

In the case of marine installations, and particularly so for naval purposes, the enlargement in volume could be best secured by giving the boilers greater height. In connection with this matter it may be incidentally stated that heretofore in naval construction the installation of a protective deck on gunboats and protected cruisers has limited the height of naval boilers. Now that the usefulness of a protective deck in other than armored cruisers and battle ships has been seriously questioned, it would appear as if the height limitation of boilers installed in naval ships of moderate displacement should not be so severe. In the case of the armored cruiser and battle ship the gain in efficiency and endurance that would be obtained from increasing the height of boilers fully warrants the designing in those vessels of a higher arched protective deck.

MECHANICAL BURNERS.

For marine purposes it has been desired that burners should be installed capable of effecting vaporization of oil without the aid of any intermediary of steam or compressed air. The direct use of steam entails a corresponding loss of fresh water, which in the case of ships undertaking long voyages means considerable financial loss, especially if an extra amount of fresh water has to be carried in tanks or double bottoms, or has to be made up by the expensive distilling and condensing operations of the evaporator. In stationary and land practice this loss of fresh water may be of no serious consequence, but for marine purposes the use of steam as an atomizing agent means a further additional charge against the ship, whether the extra water used must be obtained by distillation or whether a dead weight of water must be carried in the double bottoms.

Where compressed air is used as a medium with which to effect praying, although no direct loss in fresh water is involved, the introduction of air compressors encroaches upon the weight and space allowed for installation of machinery and requires considerable attention in the nature of upkeep and repairs. The character of the air compressors necessary to supply sufficient air for a number of marine boilers is such that the space occupied by them in an engine room or other compartments is considerable. The horsepower required to operate compressors is also quite an item, and to this extent involves an additional drain on the fuel.

Since the early days of oil burning, various plans have been proposed to effect vaporization by entirely mechanical means. Early inventions contemplated the use of oil running over surfaces exposed to the action of flames and the burning taking place directly on the exposed surface of the oil. All such plans proved decidedly inefficient owing to the fact that the air supply could never be brought to the burning surfaces of oil in quantities sufficient to effect complete combustion; consequently all mechanical burners operating on that plan have been long since abandoned. The next field of invention that gave indication of success was to design burners in which the oil would be sprayed positively by mechanical action.

Mechanical action can be resorted to, for the purpose of spraying oil by two general methods: First, to force oil outward under considerable pressure from a properly formed orifice, by the action of a special pump; second, by whirling or flinging the oil outward from a rapidly revolving mass or burner head.

The board recognized the fact that to conduct extensive tests of these two separate means of burning oil fuel would require a long range of experimentation, which the facilities of the Bureau would not permit. Tentative experiments were, however, conducted, and of sufficient extent to indicate a possibility for successful development of these burners. The board has previously made reference to a series of observations conducted with centrifugal burners, from which were derived a number of interesting facts. (See pages 258 to 266.)

Of the mechanical spray burners it may be said that very few have achieved success. It is obviously very difficult to devise an apparatus which is capable of dividing into a fine spray a material so thick and viscid as fuel oil. As a step to the study of how mechanical spraying can be effected, an examination could be made of certain forms of nozzles now used for water spraying or for lawn sprinklers. In these little devices we have a somewhat similar problem. It is desired to spray water by means of no other power than that resting in the pressure of the water itself. In the case of oil, as the fluid is far more viscous than water, it would seem that a greater pressure should be applied to the fluid in order to effect a corresponding breaking up of the oil into particles.

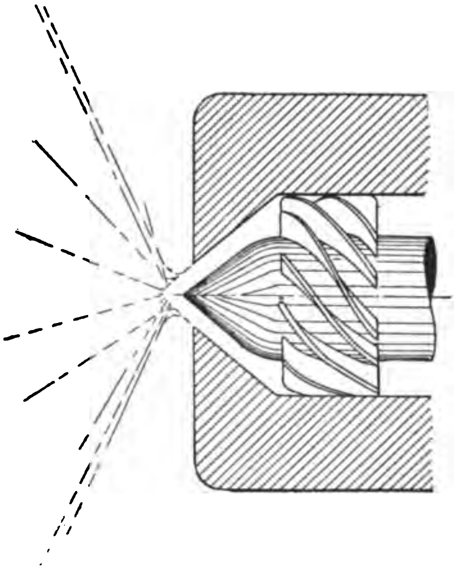


FIG. 45.—Formation of a mechanical spray, under the joint action of the pump pressure on the oil and the centrifugal action of the,screw guide blades.

In fig. 87, are shown a variety of orifices, any one of which may effect the spraying of a fluid provided the pressure on the medium is sufficient. From the experience gained with these types of orifices, it has in general been observed that the best effects can be obtained from an orifice or nozzle as shown in fig. 45, on an enlarged scale. It will be seen that the fluid passing through the orifice under the action of the heavy pressure has first imparted to it a rotary motion, caused by the introduction of spiral blades, which blades should be sufficiently near to the orifice so that the rotation of the oil will not be reduced by the action of the skin friction of the passages between the blades and the tip or orifice. The fluid, once passing the point of the orifice, then meets into collision with the various streams of fluid, and, together with the centrifugal action, the ensuing result is that the oil will be expanded or thrown off into the radiating lines, as shown in the diagram. The pressure behind the fluid, the pitch of the guiding blades, the sharpness of the orifice edges, and the form of the central cone are all important items, each of which has a relation to the final result. Burners designed on these lines can give and have given very fair results.

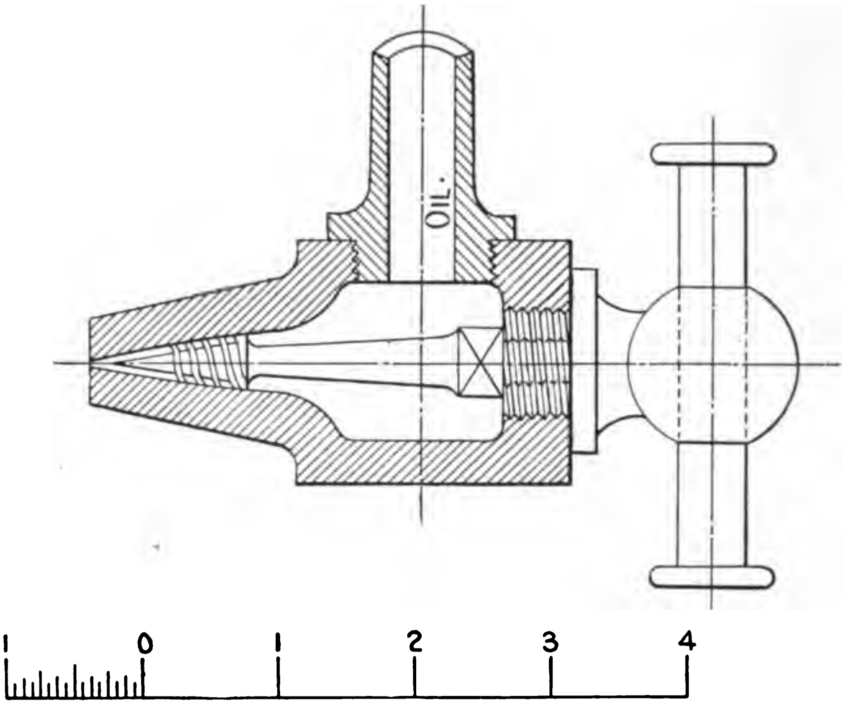


Fig. 46.—Original Korting mechanical burner.

Referring to work actually accomplished with mechanical burners, reference should be made to the successful installations undertaken by the Korting Brothers in Europe. Their first form of burner was on the lines as shown in fig. 46. From this it will be seen that the oil, under the action of the pump, is forced through a tapering screw thread and to the spraying orifice. The effect was reasonably satisfactory. Later designs by these manufacturers (fig. 47) show this burner with the orifice given, the lines somewhat resembling an injector instead of spraying outward from a sharp edge. The loss of spraying effect from the sharp edge is probably made up for, by a current of air which is swept through the small holes in the outside rim of the burner. A further improvement on the mechanical fittings of this burner is shown in the mechanical oil burner used on the Netherlands revenue cruiser *Hasenwind*. A cross section of this burner is as shown in fig. 48. The structural details are greatly modified, while the essential principles remain the same as in the previous burners. The points of difference noted are that each working part is made quickly

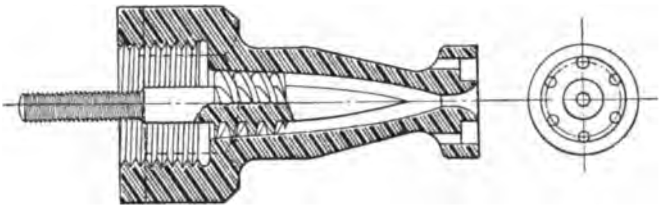


FIG. 47.—Korting mechanical burner: scale full size.

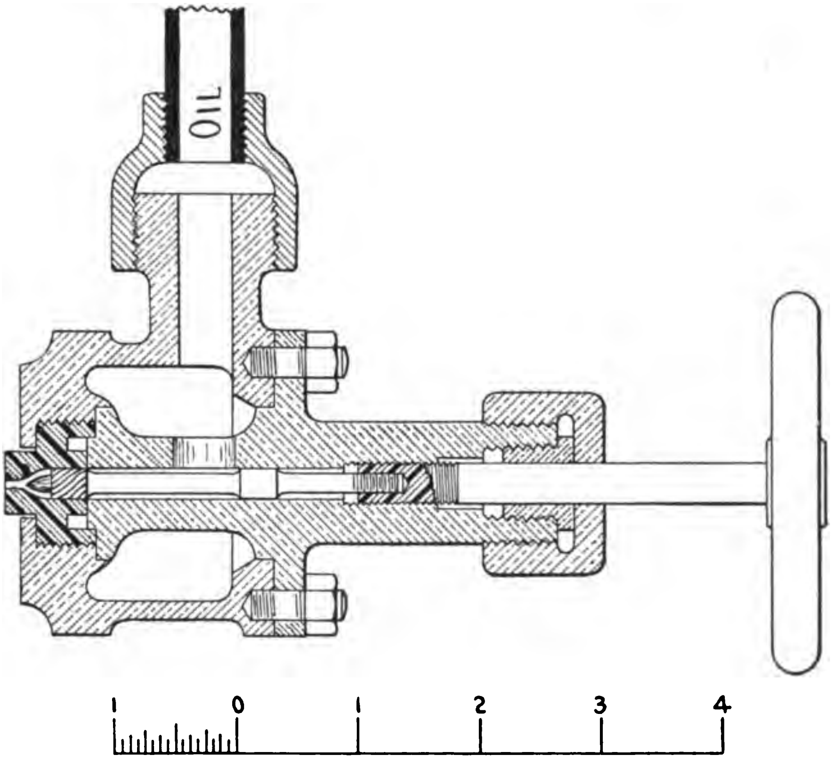


FIG. 48.—Mechanical oil burner on Nederlands's Revenue Cruiser *Hasenwind*.

removable for examination or cleaning. Burners of this type have been long in use in the service of the vessels of that country, and appear to have given satisfaction and to have produced very little smoke.

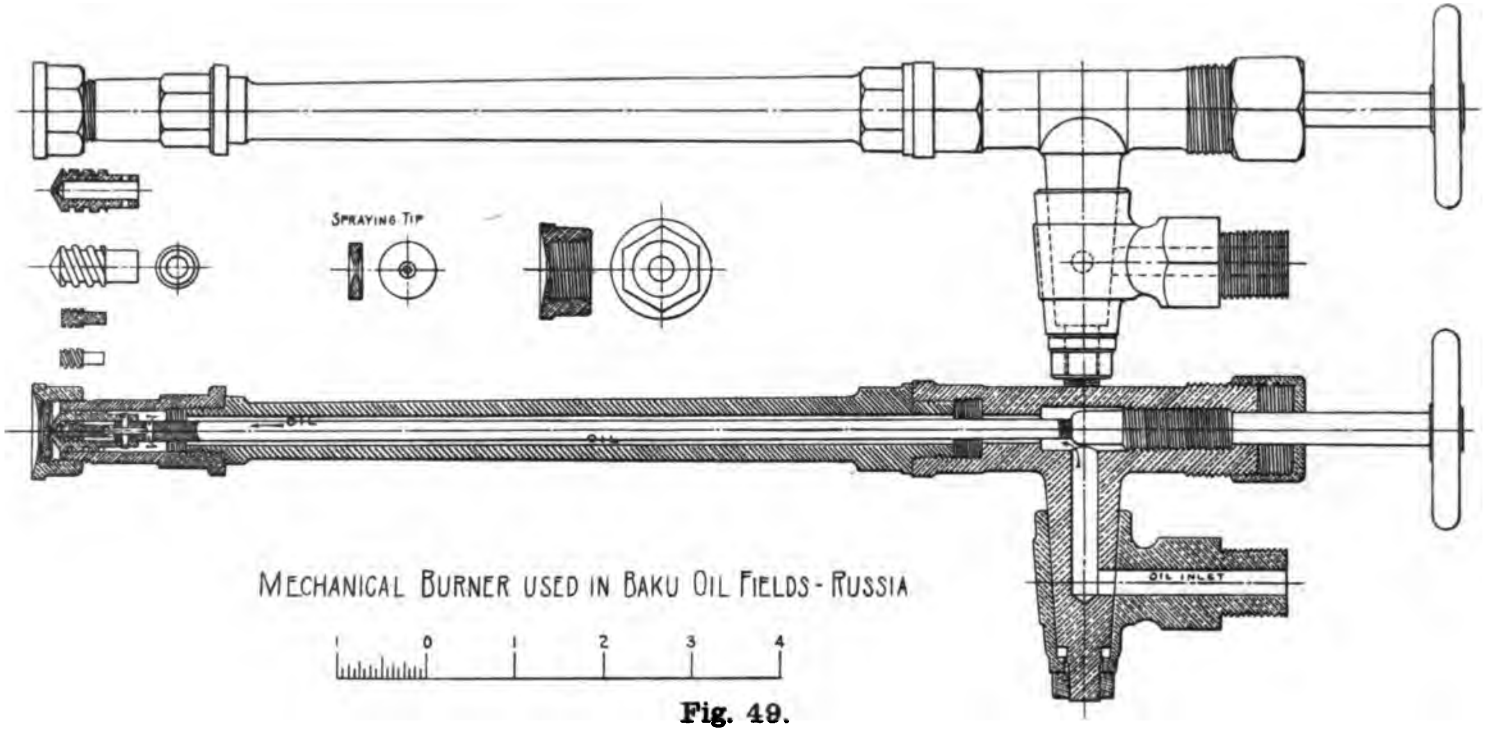
Fig. 49 shows a mechanical burner used in the Baku oil fields of Russia. It would at first be thought that burners operating in land service should not seek to be specially economical in the use of steam as a spraying medium; but as the use of a steam burner always entails the loss of water, and as the Baku oil fields are practically on the edge of a desert, where all water has to be hauled or pumped, it is therefore necessary in that locality to resort to every method possible to effect water saving; hence the development of this mechanical burner for land service. In this burner it will be observed that the spraying is effected by the action of two sets of spiral guide blades—one set within an inner tip and one set within the outer tip. It will be noted, further, that the outer spraying tip is removable; so that, as the tip edges wear, new tips can be inserted or special tips can be placed for use under certain conditions of pressure or fluidity of oil.

The experimental board, late in the course of its investigations, devised the burner as shown in fig. 50 for test purposes, to run under mechanical action, but opportunity was not presented to put it into service. As is shown in the sketch, the guide blades are very open and of steep pitch, as it was the intention to use it on California oil, which is of greater viscosity than the Texas product. The shape and type of the tip was such that changes in angles or sharpness could be quickly made, or new tips replaced as old ones became worn.

It should be noted that with all these mechanical burners the tips are required to be very small in the diameter of orifice, usually not over one-sixteenth of an inch. As the oil is forced through under considerable pressure, and as the oil carries more or less grit, the tip is therefore subjected to considerable wear, and of necessity should be made quickly renewable.

Any burner operating on the mechanical principle requires as a fundamental essential for its satisfactory operation that the oil should always be supplied under considerable pressure, probably never less than 40 pounds to the square inch, and many plants are stated to be running under regular pressures as high as 150 pounds.

It is further essential that the air supply should always be brought to as high a temperature as possible, either by superheating, as in the Howden system, or by proper arrangement of the furnace passages whereby the air can be not only made to pass between heated linings, but can be brought to impinge on the newly formed jet or spray of oil in such manner that combustion can be immediately effected. The air necessary for combustion must be under control and regulation in order to conform to the quantity of oil being forced through the orifice. With a carefully adjusted heated air supply and properly regu-



MECHANICAL BURNER USED IN BAKU OIL FIELDS - RUSSIA

Fig. 49.

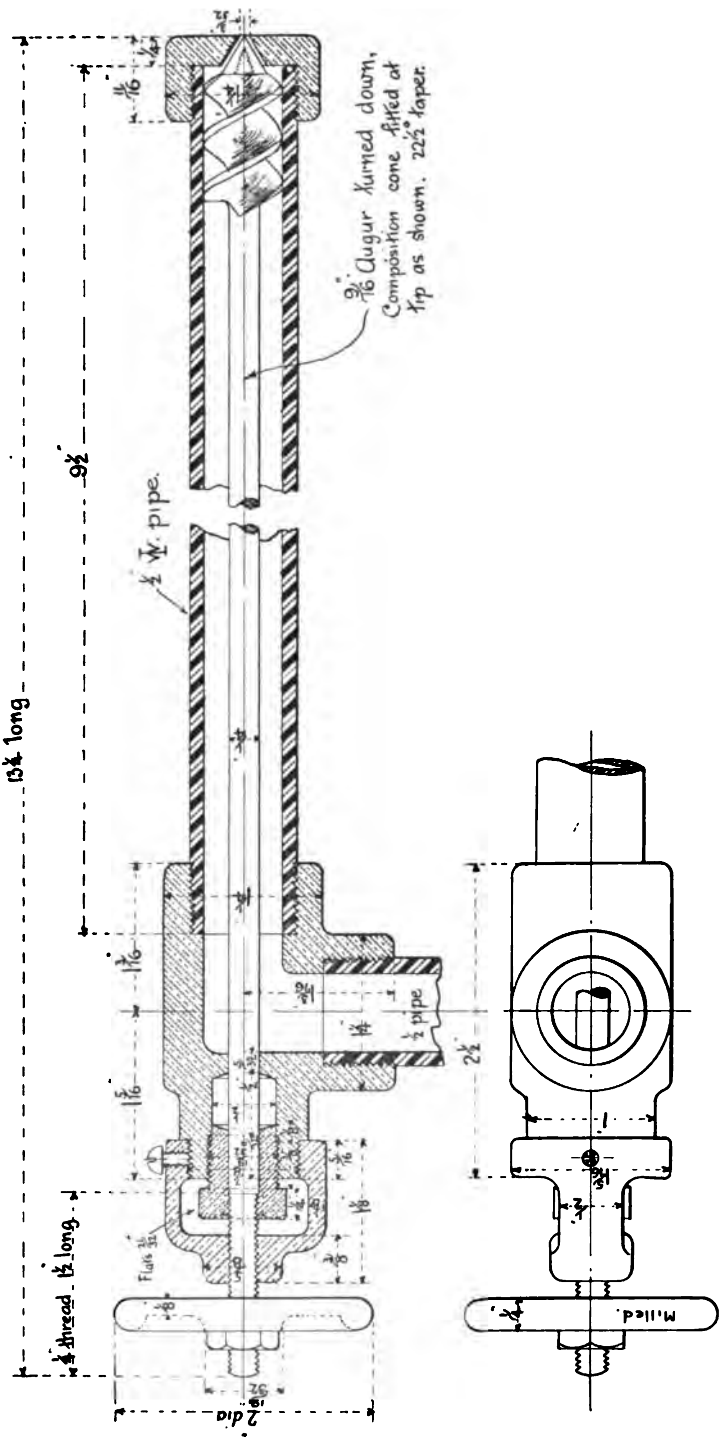

13¾" long
9½"
9/16" Augur turned down, Composition cone fitted at tip as shown. 22½° taper.
½" W.I. pipe
½ pipe
2¼"
2" dia
¼" thread 1½ long
Flats
Milled

FIG. 50.—Burners for mechanical spray, designed for use by the Naval Fuel Oil Board.

lated burners this mechanical method of spraying oil will undoubtedly give satisfactory results.

In fig. 51 is shown the arrangement of furnaces as installed in the Nederland steamer *Brouwer*. It will be noticed that the mechanical appliances or burners spray into a furnace in which there has been substituted for the grate bars a special design of cast-iron ribbed plates. In what would appear as the ash pit there is placed a thin sheet-metal partition, so arranged that the entering air passes in on the lower side of the partition and receives in transit some heat from the lower corrugations of the furnace. This air then passes to the upper side of the partition, between the cast-iron ribs, which are very hot, owing to their proximity to the flame, and having thus become heated the air strikes against the freshly formed spray of oil, rapidly producing intense combustion. A seeming objection to this furnace would be that the upper part of the furnace is entirely unprotected by brickwork, consequently the fuel oil is likely to strike the cold plates, whereas no oil should in the early formation of the spray strike anything but highly heated brickwork. However, as thus arranged, these furnaces appear to have afforded reasonable satisfaction and immunity from smoke.

In the opinion of the board a more efficient arrangement could be obtained by using furnaces with extension fronts and provided with air inlets so devised as to give the entering air not only a higher temperature, but also a considerable spiral action. Furnace designs of this kind are as shown elsewhere in this report in fig. 98, Forms IV and V, and fig. 104, Forms VIII and VII.

Mr. R. A. Meijer, superintendent engineer, Koninklijke Paketvaart-Maatschappij, of the Nederlands-Indies, has adopted mechanical spraying of the Borneo oil in a number of the large steamers of that company, and his views are as thus set forth:

> In arranging the ordinary furnace of a marine boiler for the burning of liquid fuel the following important points have to be kept in view:
>
> (*a*) With a single mechanical burner probably no more than a quantity of oil sufficient for about 80 I. H. P. per hour can be injected into the furnace (enlarging this burner would impair its good working), and this often renders it necessary to place two and sometimes three burners on each furnace to allow the full quantity of fuel necessary for the creation of the desired steam, to enter the furnaces, and ample room should thus be given on the furnace front, as well as in the furnace itself, to allow for these additional burners.
>
> (*b*) The air necessary for combustion—about 200 cubic feet per pound of oil—has to be well heated before coming into contact with the particles of fuel, and this contact should be as intimate as possible to allow every particle of oil to be well surrounded by the hot inflowing air. Care should be taken to allow the fresh air from without, a free access to the furnaces, and therefore the stokehold gratings on deck should be made large and in accordance with the quantity of air necessary for combustion.
>
> (*c*) To maintain a proper contact between air and fuel the air flowing in should surround the injected oil on all sides in the furnace.

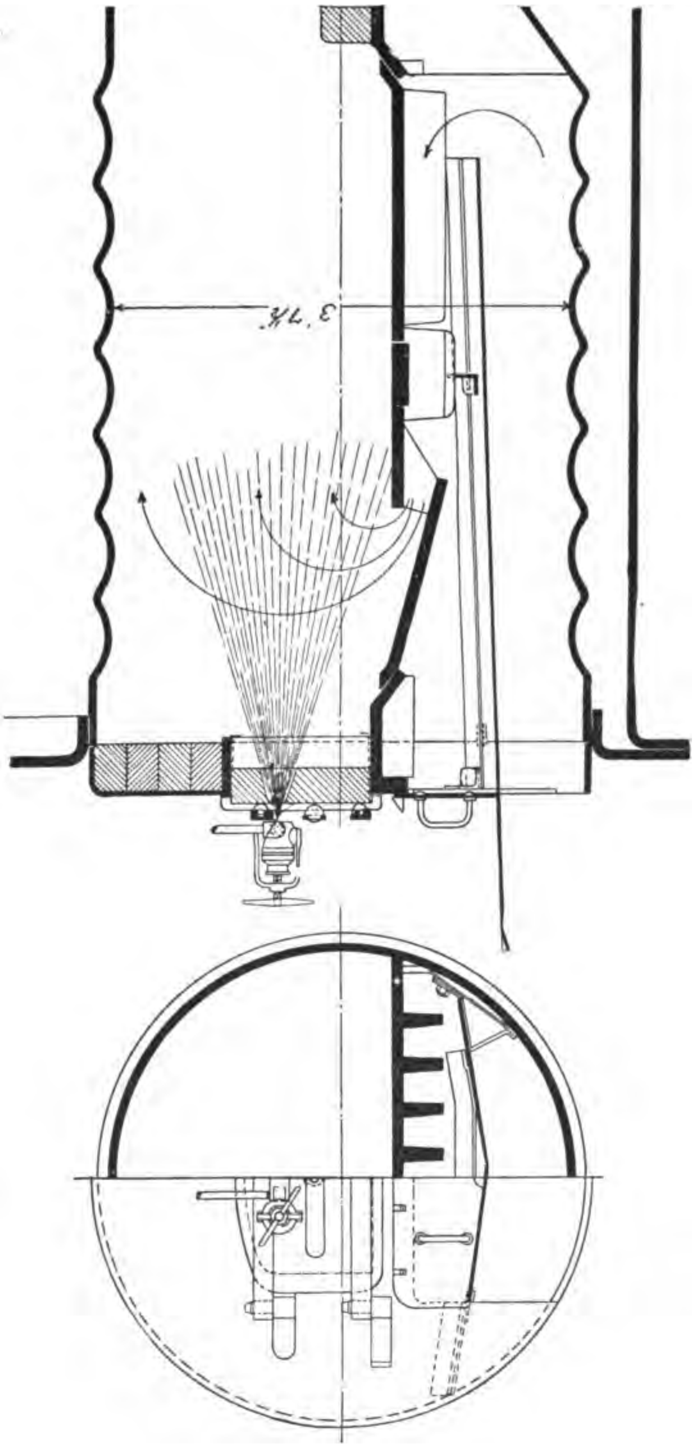


FIG. 51.—Furnace arrangements for burning liquid fuel on the Nederland's steamer *Brouwer* using mechanical spray burners.

> (*d*) The jet of oil fuel must spray freely into the furnace and burn there without touching any of the boiler parts or brickwork, as this would cause the formation of carbon.
>
> (*e*) A good quantity of brickwork is necessary in the furnace, not only to act as a bridge to prevent the escape of the gases unburned through the funnel or as a protection for the back of combustion chamber, but also to allow the brickwork, after being heated, to act as a heat accumulator, thus constituting an aid in keeping the furnace at a high temperature.
>
> (*f*) The opening of the fire bridge for the outflow of gases should be tried very accurately, as an opening too small or too large would produce a thick smoke. Experience with Borneo oil fuel showed 0.6 square feet of opening per burner to be about the required size.
>
> To these the experimental board would certainly add the following:
>
> (*g*) Careful filtration of oil is an essential. As the spraying nozzle must have a fine aperture, any chip or particle of sand or dirt will easily clog it, therefore filters of wire gauze should be fitted of mesh at least one-half the diameter of orifice. It would also be found beneficial to use double strainers.

It is also important that the temperature of the fuel oil should be raised by some system of gentle heating in order to increase the fluidity of the oil, but it should be noted that this heating should not be carried much over 140° F. Perfectly cold oils of certain fields are at low temperatures, very viscous, and in fact so thick at temperatures below 40° that many have the consistency of a tar rather than oil.

The sprayed oil fuel after leaving the nozzle of the mechanical burner should show an even light gray color as water vapor. The brown or dark line in the sprayed oil proves that there is some obstruction in the burner, and the needle or nozzle should be instantly taken out and cleaned or replaced by a spare one. The construction of most of the mechanical burners makes this change an easy matter.

OIL-FUEL TESTS ON BOARD THE STEAMER TEBE.

The increasing attention devoted to the mechanical spraying of oil without the use of any intermediary of compressed air or steam to effect vaporization induced the board to take cognizance of the work being done in this direction on the Continent.

As an example of carefully conducted tests carried out on a scale sufficiently extended to secure fair results, the board appends information obtained in a series of runs of the steamship *Tebe*, as conducted under the supervision of the Engineer Salvatore Orlando, of the Navigazione Generale Italiana, as published in the Rivista Marittima, March, 1904, and translated by the Office of Naval Intelligence, United States Navy Department.

> The steamer *Tebe*, of the Navigazione Generale Italiana, recently made a voyage for the purpose of testing oil fuel in combination with a Korting spraying burner. In view of the good results secured during these tests, it is deemed desirable to give some data concerning the working of this installation.
>
> The *Tebe* has a triple-expansion engine, built by the Odero Works, of 1,973 I.H.P. Steam is supplied by two double-end Scotch boilers of six furnaces each, the entering

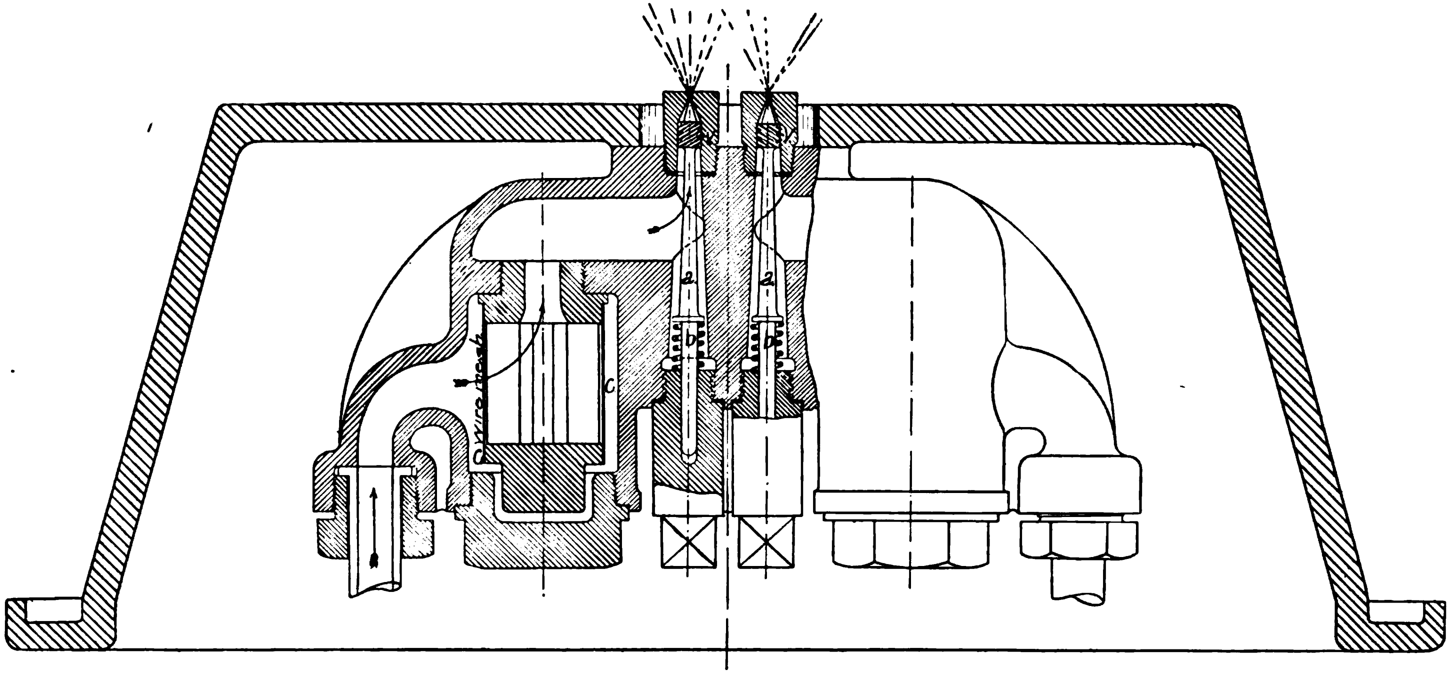


FIG. 52.—Mechanical spray burners of the Italian steamship *Tebe*. Duplex burners of the Korting type, in special burner head with removable oil strainers; *a*, steel spindle, with right-handed and left-handed screw; *b*, spiral springs; *c*, net filters.

air being heated by the Howden system. The total heating surface is 6,458 square feet, with heating tubes fitted with retarders.

In these experiments Texas petroleum was used, which was obtained from the oil depot at Alexandria, Egypt. Being in the crude state, or nearly so, this fluid is very viscous and does not possess the searching qualities of refined petroleum, and thus the fuel may be kept with perfect safety in an ordinary double-bottom compartment of the vessel. It was thus kept on board the *Tebe.*

In order to allow the noxious gases of the crude petroleum to escape, every oil compartment was fitted with pipes rising above the upper deck, with elbow extremities inclosed in a safety casing turning downward.

The point of ignition of the fuel used was found to be quite high. Partial ignition only occurred at 196° F. and complete ignition at 230° F. This is considerably beyond the minimum limit of safety required by Lloyd's in London. The density of the fluid burned was 0.931 at 60° F., 0.905 at 130° F.

It contained less than 1 per cent of sulphur and the residue of ashes was 0.021 per cent.

The oil is drawn from the double bottom by means of a Blake pump of a capacity of 12 tons an hour and then conveyed to two service tanks of 10 tons each, designed to supply alternately the necessary oil to the burners.

The main object of these tanks is to separate the petroleum from any water which it may hold in suspension.

In the bottom of these tanks is a network of diaphragms forming rolling divisions which prevent the water, after having been separated, from again mixing with the oil in consequence of the motions of the steamer.

Above these divisions, which are about 6 inches in height, is a steam coil for heating the oil to 140° F.

Each tank is fitted with a gauge for measuring the oil, a receptacle for collecting the water in which is fitted a gauge for measuring, and a pipe for drawing off the water, a cleaning orifice, a gas escape pipe, an overflow pipe, etc.

It was estimated that the consumption would be about a ton of oil per hour, and as a consumption of two tons was never permitted, each tank would then serve as a reservoir for about eight hours' operation, during which time the water in the tank not in use would have time to separate from the heated oil, owing to the difference in density.

The density of the petroleum at 130° F. being equal to 0.905, as stated above, this separation was effected rapidly, and the water which gathered at the bottom of the tank soon appeared in the gauge of the water-collecting receptacle and was easily drawn off.

The suction pipe from these tanks has a cock just above the rolling divisions and thus practically prevents even a small quantity of water from being conveyed to the burners.

The spraying of the fluid into the furnaces is effected by means of two small Worthington horizontal pumps, used intermittently, of a diameter of 3 inches, with a metallic net suction filter. The crude petroleum drawn from the surface tanks is forced by these Worthington pumps into heaters into which the temperature of the fuel oil is increased from about 135° to 185°. The oil supply after passing through a net filter (two of which are provided for intermittent service) (*c*, fig. 52) finally reaches the furnaces through the mechanical burners or sprayers.

The burner consists of an iron casing having a discharging orifice about 0.05 inch in diameter, with a conical opening toward the interior of the furnace. Inside of this casing is a steel spindle, *a*, which is held by a spiral spring in a central position relative to the discharging orifice.

In order to reach the orifice in the casing the fuel oil must pass between the spirals

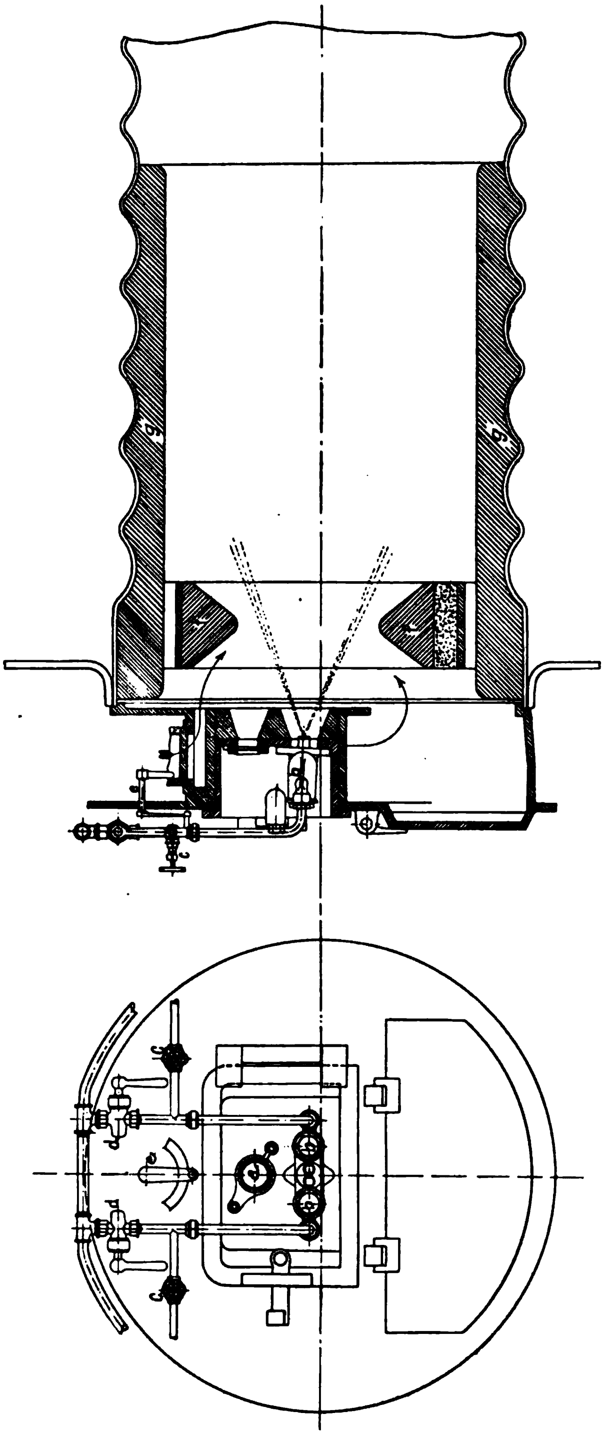


FIG. 53.—Furnace details of the mechanical spray burners, installed on the Italian steamship *Tebe*. *a*, sight hole; *b*, burners; *c*, steam-regulating valve; *d*, oil cocks; *e*, air-regulating valve; *f*, ring of refractory material; *g*, casing of refractory material.

of the triple-thread screw *r*, taking on a rotary motion when worked under pressure of 45 pounds per square inch. Owing in part to the restricted space between the spirals of the screw, and partly to the limitation of the circular space formed during rotation, as well as to centrifugal force developed, the oil is completely atomized and enters the furnace in the form of a funnel rather than of a cylinder. In each furnace there are two burners, 1¼ inches apart, which may be operated independently of each other. Owing to the proximity of these burners the axis of the two cones of flame would intersect each other. In order to obviate the effect of this neutralization of rotation at the colliding point, the screw of one burner has been made right-handed and the other left-handed, and therefore the two oil cones would not strike each other, but rather aid one another in their motion.

The pressure of the oil necessary to effect good combustion is about 45 pounds. Where it is desired to increase or reduce the rate of combustion the pressure must be raised or lowered.

The air requisite for combustion is introduced into the furnace through the ordinary Howden openings. The ring *f*, as will be seen from the drawing (fig. 53), compels the air requisite for combustion to mix intimately with the two oil cones, and this is attested by the practical immunity from smoke as observed during the experiments.

The Korting company, which made the oil-fuel installation, had guaranteed to secure an output of evaporation of not less than 2,865 pounds of water at a steam pressure of 190 pounds with feed water at 158° F. This heating of the feed water was obtained by means of an ordinary Weir heater.

For measuring the feed water the following method was employed: A reservoir or tank for the feed water was installed alongside the air pump. The capacity of this receptacle was accurately measured and subdivided into quantities of 26.4 gallons by appropriate marks on the gauge glass with which it is fitted. . At the moment of observation the suction of the feed pumps was closed, so that the water, after filling the chamber of the air pump, flowed into the tank and indicated the height in the gauge.

By measuring with a second counter the time employed in passing from one measure to another, the attendant could deduce the feed water per hour corresponding to the rate of the engine at that moment.

Simultaneously the quantity of oil consumed was accurately measured by noting the drop of the oil in the gauge glass. There was thus obtained the two factors essential for determining the quantity of feed water evaporated per unit of liquid fuel.

A careful observation showed that 52.8 gallons of water at a temperature of 96.8° F. were evaporated every fifty-four seconds. There was an hourly consumption of 280 gallons of oil, and as the density of the oil, as previously stated, was 0.905, the consumption per hour by weight was 2,112 pounds. The quantity of feed water evaporated per hour may be assumed to be about 20,000 pounds, and therefore the evaporation of water per pound of fuel was 13.77 pounds.

Except for the fact that the steam jet appliance—which had been installed for clearing obstructions which formed on the nets of the filter—proved inadequate, the general operation of the plant was very satisfactory.

The choking up of the filters occurred quite frequently; so much so that at the end of a few hours of operation all the filters had to be taken down in turn to be cleaned. These obstructions were first indicated by the increase of the pressure of the oil in the heaters as well as by the appearance of smoke in the furnaces.

A careful examination of the deposits formed on the nets of the filters showed that the obstruction was not a foreign substance carried along by the oil, but rather carbon held in suspension in the oil itself. The formation of this carbon deposit in the oil was probably due to the increase of temperature to which the oil had been subjected in the service tank and the heater.[a]

As the entire oil-fuel installation had been favorably passed upon by a Government board of experts, the steamer was enabled to start on December 27, 1903, to Alexandria.

During the first period of the voyage—from Genoa to Leghorn—the objectionable feature of obstructions forming on the nets of the filters having again appeared, all the nets were taken off, with the exception of that of the filter on the suction pipe. In this manner the deposits, which were nothing other than combustible matter, were thrown into the furnace. The work then became regular, and the voyage to Alexandria was completed without further inconvenience.

During the various runs several experiments were made with forced draft and fuel consumption noted, which are summed up in the following table:

Route.	Duration of observation.		Oil consumed.	Consumption per hour.	Mean number of revolutions per minute.	Mean development in indicated horsepower.	Consumption per indicated horsepower per hour.
	h.	*m.*	*Pounds.*	*Pounds.*			*Pounds.*
Genoa to Leghorn	2	44	5,692.5	2,016.8	84.9	1,923	1.067
Leghorn to Naples	17	40	36,230	2,050.5	85.2	2,012	1.005
Naples to Messina	11	21	23,225	2,046.2	83.4	1,854	1.087
Messina to Alexandria, Egypt	44	50	88,919	1,983	84.2	1,903	1.027

The operation of these mechanical burners was not accompanied by any noise. Not only did the steam pressure remain constant, but the level of the water in the boilers was always maintained. The labor and care of operating the installation was therefore reduced to a minimum. It was also observable that there was a slight variation of temperatures in the fireroom.

In this first voyage there was quite a loss of fuel, due to the fact that the filters and the burners had to be repeatedly dismantled in order to examine and clean them. There was also resulting loss of oil from the attendant dripping which followed the examination and dismantling of burners and filters.

Eliminating unusual losses of oil, it may be assumed that the Texas petroleum as secured from the oil depot at Alexandria and burned with a Korting apparatus[b] in an ordinary Scotch boiler fitted with the Howden draft system will result in a consumption of about 1 pound of fuel per horsepower for marine purposes where there is an ordinary triple-expansion engine. The consumption of Cardiff coal under like conditions may be assumed to be never less than 1.50 pounds of fuel per indicated horsepower.

---

[a] As noted elsewhere in this U. S. Naval Fuel Oil report, it has been observed that the prevention of deposits of hydrocarbon can only be provided against by not heating the oil to a temperature exceeding the critical point at which such hydrocarbons are deposited. The chemical analyses of various oils shows the point at which such deposits commence to form.

[b] Special attention is called to the fact that these results secured with the Korting mechanical burner agree very closely with the data secured from oil-fuel installations where the fuel is atomized by either steam or air.

RESULTS OF TRIALS WITH KORTING BURNERS WITH INDUCED DRAFT ON MARINE BOILERS.

The following results of tests made with the Korting burner, using the oil fuel sprayed by a mechanical means, appear to have been conducted with great accuracy, and the results are such as to be worthy of careful analysis.

The Wallsend Slipway and Engineering Company (Limited) have been most successful in the application of liquid fuel as a means of generating steam in marine boilers. The method of burning liquid fuel adopted by them is the Korting system.

The boiler on which the system was shown at work is of the ordinary marine type designed for forced draft. It is 12 feet 6 inches in diameter by 11 feet ½ inch long, with two large furnaces 3 feet 7 inches in diameter. The tubes are 2½ inches in diameter and fitted with retarders. The boiler was completely inclosed with an air-tight house, so as to show the system working under both natural and forced-draft conditions. By leaving the doors open the burners were first worked under natural draft. The stokehold was then closed and the fan started, when it was shown that the system can be worked with almost any degree of air pressure. Starting with a very low pressure, it was increased until 4½ inches was recorded on the gauge. On a previous trial it was found that with the boiler as designed it was not desirable to go to a higher pressure of air, as the heating surface was not sufficient to absorb the heat generated.

With greater pressure and larger tubes, however, a much higher rate of combustion could be obtained. Throughout the trial no smoke was visible at the chimney, showing that combustion was perfect.

COMPARISON OF OIL-BURNING TRIALS WITH THE KORTING PATENT BURNER AND COAL-BURNING TRIAL ON MARINE-TYPE BOILER.

Particulars of boiler with which trials were carried out: Mean diameter, 12 feet 6 inches; mean length, 11 feet; number of furnaces, 2; inside diameter of furnaces, 3 feet 7 inches; number of tubes, 262; external diameter of tubes, 2½ inches; total heating surface, 1,695 square feet; grate area under coal, 40 square feet; working pressure, 120 pounds per square inch; all tubes fitted with retarders.

	Coal trial.	Natural draft (oil fuel) trial.	Oil fuel (stokehold air pressure 1½ inches).
Duration of trial ....hours..	6	5	4
Average steam pressure ....pounds..	113	115	105
Average temperature of feed water ....° F..	55	80	107
Pressure of oil at burners........pounds..	....	75	140
Temperature of oil at burners........° F..	....	240	110
Quantity of water evaporated per hour........pounds..	7,558	7,756	14,951
Quantity oil burned per hour ....do....	....	633.4	1,222
Quantity coal burned per hour........do....	974.3	....	....
Water evaporated per pound of oil (actual)........do....	....	12.24	12.23
Water evaporated per pound coal ....do....	7.76	....	....
Water evaporated per pound oil from and at 212° F .do....	....	14.45	14.06
Water evaporated per pound coal from and at 212° F.do....	9.31	....	....
Quantity of water evaporated per hour from and at 212° F........pounds..	9,060	9,152	17,193
Total quantity ash ....do....	283	....	....

NOTE.—Class of fuel, coal trial, best Mickley picked; natural draft (oil fuel), Texas oil; oil fuel (stokehold air pressure, 1½ inches), Texas oil.

To show the excellent results which have been obtained with the Korting burner, we may add that an evaporative test has been carried out, when an evaporation of over 16 pounds of water from and at 212° F. was obtained per pound of oil fuel consumed.

The following results are obtained by the Korting burner in conjunction with induced draft:

Particulars of boiler with which trials were carried out: Mean diameter, 12 feet; mean length, 11 feet; number of furnaces, 2; inside diameter, 3 feet 9 inches; total heating surface, 1,200 square feet; external diameter of tubes, 3¼ inches. All the tubes, except the two bottom rows, were fitted with retarders.

Duration of trial	6 hours.
Class of fuel........	Texas oil.
Average steam pressure (gauge)	140 pounds.
Average temperature feed water........	53° F.
Vacuum at fan	1¾ inches.
Vacuum at furnace door	⅝ inch.
Vacuum at ashpit door	⅝ inch.
Temperature of air entering furnace (left)........	250° F.
Temperature of air entering furnace (right)	290° F.
Temperature of gases at fan suction........	465° F.
Pressure of oil at burners	105 pounds.
Temperature of oil at burners	162° F.
Total quantity of water evaporated	65,500 pounds.
Water evaporated per hour	10,917 pounds.
Total quantity of oil consumed........	4,920 pounds.
Oil consumed per hour	820 pounds.
Water evaporated per pound of oil (actual)	13.31 pounds.
Water evaporated per pound of oil (from and at 212° F.)	16.13 pounds.
Water evaporated per hour (from and at 212° F.)........	13,231 pounds.
Revolutions of fan per minute........	260.

THE OIL-FUEL INSTALLATION OF THE STEAMSHIP CITY OF EVERETT.

The board not only made a very careful and complete inspection of the oil-fuel installation of this vessel, but through the courtesy of the fuel-oil department of the Standard Oil Company the opportunity was presented to go down the Delaware River for a considerable distance on the boat. The method of operating the plant both for auxiliary and for general steaming purposes was therefore observed. The details of the general arrangement of this oil-burning plant and its requisite auxiliaries are shown in fig. 54.

The burner used was one designed by the officials of that company (fig. 56). The distinguishing feature of this appliance is the fitting of a plug at the end of the burner and the drilling of a series of radial holes in the plug whereby a short and uniform flame was secured.

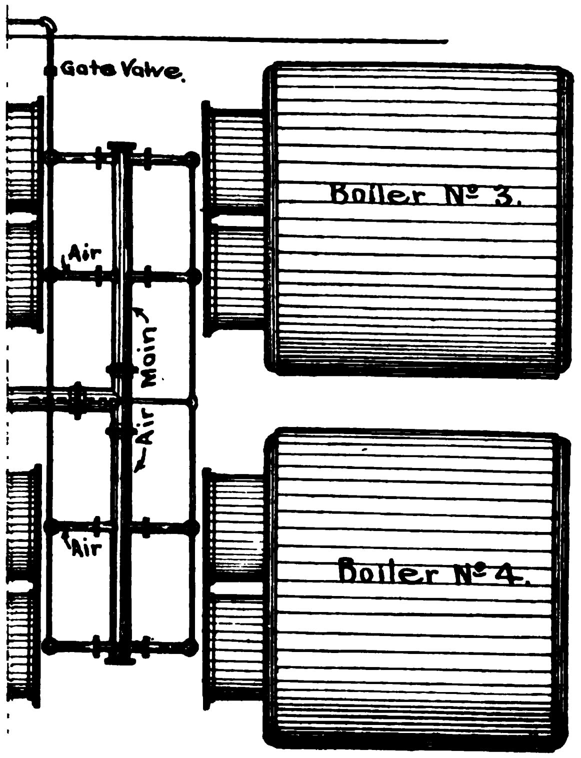
The burners are arranged in detail as shown on fig. 55, and the furnace itself is lined with a fire-brick ring for a distance of 3 or 4 feet from the front end.

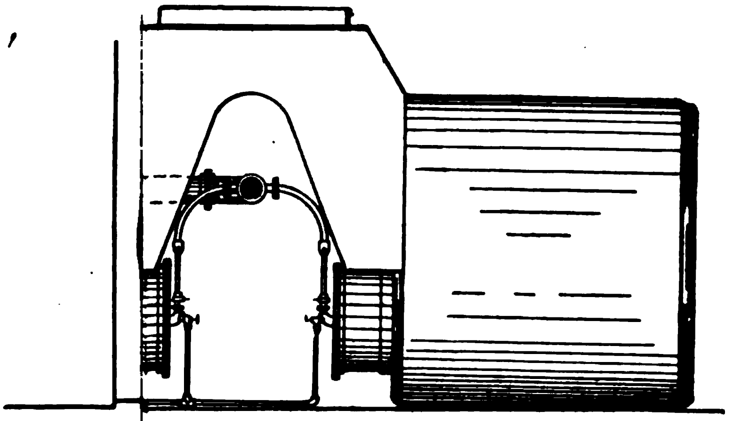
By reason of the design of the burner no baffle or spatter wall had been installed. As shown in sketch, an extension had been made to the front of the furnace, and there is no doubt that such extension caused complete combustion to be effected before the gases reached the tubes.

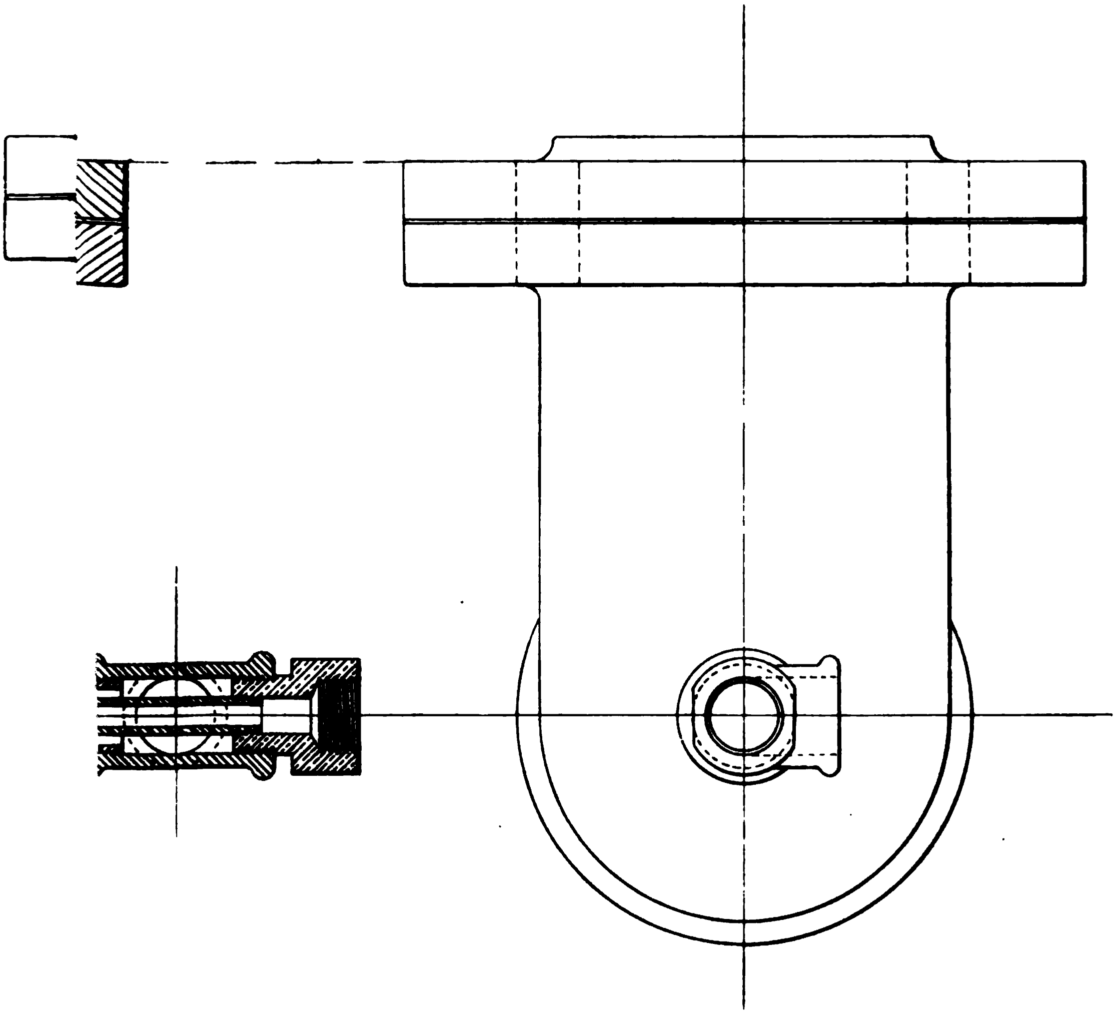
With the air taken in at the bottom of the furnace extension there is an opportunity given for the gases requisite for combustion to combine with the atomized oil in the front portion of the furnace.

There are two positive blowers driven by independent vertical engines. Only one blower is used, the other being held in reserve. The oil pumps are also in duplicate. There is a small auxiliary blower driven by a gasoline engine. This blower furnishes air for one burner in each furnace, and runs under a higher pressure than the large main burners. These small burners are also connected so as to use steam as an atomizing agent in case of necessity. When starting fires the gasoline engine is run until steam is raised on one boiler and the main air plant started. When lying at anchor the main blower is stopped and steam is held by the auxiliary plant, and should it be necessary to stop this before starting the main blower the auxiliary burners can be operated with steam. The furnaces are lined 2 feet 8 inches from fire door with fire brick, and have 28 inches extension to fronts. The burners fire directly into the extensions with no baffles, there being two main burners to each furnace. The air for combustion is taken in through bottom of extension.

The general arrangement of fuel oil tanks and cargo oil tanks of this whaleback steamer are as indicated in the inboard profile shown in fig. 57.


Gate Valve.
Air
Air Main
Air
Boiler No. 3.
Boiler No. 4.





3.

CLASSIFICATION OF OIL BURNERS.

There are on file in the United States, British, and Continental patent offices several thousand designs of oil-fuel burners. These records show that men of almost every vocation and profession consider themselves competent to design such oil-fuel appliances. The condition of affairs in this respect has been expressed by one writer as follows:

> The oil-fuel burner has furnished almost as much work for the Patent Office as the car coupler, and at the present time very few, if any, of these patents are designed in accordance with the fundamental principles that should govern the construction of such devices.

While the belief is general that these various patents differ in principle, an investigation of their design and construction shows that all can be grouped into a few primary classes. By combining features of each of the groups and by effecting simple changes in details of special types it has been made possible to patent thousands of designs. It was only because the price of oil had increased on the Atlantic coast to almost a prohibitive price for its commercial and maritime use as a fuel during the past few years that hundreds of additional patents were not taken out.

It was but a few weeks after the oil tests began before the Bureau of Steam Engineering was requested by many inventors to test their special appliances. The attention of individual members of the board was also called to the merits of numerous designs of burners. It then became evident that unless it were possible to classify the burners and test only representative types of each group the experiments would extend for an indefinite period. A general examination of the patents taken out clearly showed that the important elementary principles governing the designs of every satisfactory oil burner are comparatively simple and few, and that the most efficient burner for any purpose is, in general, the simplest piece of mechanism, using the least amount of steam or air for atomizing purposes.

The various schemes for superheating the atomizing agent or for converting the oil into a gas before leaving the burner are of doubtful value. One has only to consider the amount of air requisite to secure complete combustion to realize the improbability of accomplishing this purpose within the burner itself. The development of the successful oil burner has thus been in the direction of cheapness and simplicity. Extended experiments, as well as careful research and calculation, have shown the imperative necessity of providing for proper sizes of orifices, and thus, simple as the oil burners may appear to be, the best of them represent in their development years of extended study, investigation, and practical experience.

The ordinary user of liquid fuel should avoid the purchase and installation of any type of burner whose capabilities are advertised as extending beyond atomizing and supplying the oil uniformly and continuously. No burner should be used which has not been designed and manufactured by firms who have had experience in the work. The experienced and successful manufacturers of oil-fuel appliances make but few claims for their special burners. These experts recognize the fact that it is good workmanship, high quality of material, and extended experience in the general installation of oil-fuel appliances that are the determining factors in its successful use.

The actual form of the burner, independent of the general installation, will have but little influence in determining either the economical efficiency, the evaporative capacity, or the uniform burning of liquid fuel. For some purposes the single form of "Y" burner, where the fuel enters through one branch and the spraying or atomizing medium enters through the other branch of the angle, might be found answerable. In every form of efficient burner, however, it is imperative that there be fitted valves of such design that a uniform and small supply of oil be admitted and that the pressure of the spraying medium be absolutely under control.

In selecting the desirable form of burner for practically any purpose the essentials demanded are: A design capable of easy installation and operation, and a form of construction that will permit the rapid examination and quick renewal of parts. From various causes it will be found practically impossible to prevent foreign substances occasionally choking the burners, even though the liquid fuel before reaching the burners is heated and made to pass through a series of strainers. Any form of burner which does not permit rapid examination and clearing out of all foreign substances is unfitted for marine use.

The board found that there existed upon the part of every expert a tendency to install too few burners. As the clogging of these burners will occasionally occur, the only means of subjecting the boilers to uniform conditions is to have an installation of reserve burners, so that the extra ones could be quickly thrown into use. When it is considered that the cost of installing a few extra burners is trifling as compared with the total cost of an oil-fuel installation, there should be no hesitancy in providing a sufficient number of burners, for a reserve appliance may secure a more uniform evaporative efficiency, as well as a greater output, and will help overcome some of the serious objections that have been experienced in the use of liquid fuel.

One of the special advantages claimed for the use of liquid fuel, that the work of the fireroom force is not only lessened but made less onerous, will only be realized by an installation wherein there is a reserve of burners. All the burners should be so installed that their flame should point somewhere near the center of the furnace, and special care should be taken that the oil product is not injected directly upon a heating surface.

The following grouping or classification of burners shows how simple are the guiding principles of construction of the thousands of forms that have been patented. The sketches show the salient differences of design, and should require but little explanatory text.

Burners.—There are two methods of burning oil which are mentioned in this report, and which the board considered it not advisable to investigate, for the reason that either of the methods required use of purified oil rather than crude oil or petroleum. One of these is the method of open pans, hearths, drips, cups, etc., while the other is a gas furnace in which oil is first reduced to gas and then burned.

The use of crude oil or petroleum in either of these arrangements of apparatus, while possible for a short length of time, is not satisfactory as a continuous working method of forming combustion, and therefore can not be regarded as efficient or practical. The reason for this ineffectiveness is due to the fact that all crude oil contains a heavy, solid base, or hydrocarbon residuum. In the case of the Pennsylvania oils a heavy paraffin constitutes the base, while in the California oils the base consists of heavy asphalt. Oils of other localities have varying quantities of either or both bases. Any burner or method which deposits these heavy bases is sure to become clogged and choked. As the separation of the hydrocarbons from the bases often takes place at temperatures sometimes as low as 130°, it is readily seen that any heating of oil in pipes, pans, retorts, etc., by the action of the flame, or by indirect radiation whereby this temperature is exceeded, is sure to produce a choking or clogging of the apparatus.

Although these heavy hydrocarbons are of themselves good combustibles, yet if not supplied with a sharp air current while in combustion full burning can not be effected, and a remaining hard, clinker-like coke is left behind, a substance difficult to remove except by outside mechanical interference. Any boilers or furnaces equipped with apparatus of this kind, the board readily foresaw, would lead to difficulties and needless experimentation.

To classify properly the remaining types of burners into distinct groups it was deemed desirable that the multitudinous numbers and varieties of design should be arranged, either in accordance with some ruling form of construction or by reason of requirements of operation. After a careful analysis of various types, it was observed that five general classes would cover practically all of the main features of construction, and from these five classes various modifications could be made.

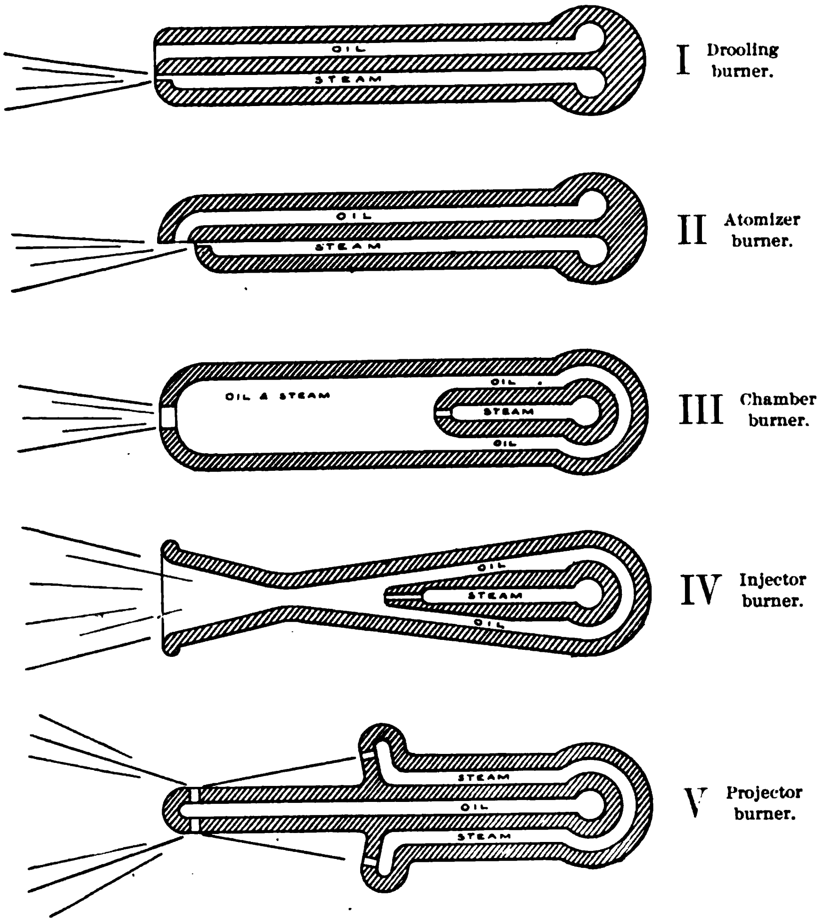


FIG. 58.—Oil burner classification.

These five classes of oil burners may be thus grouped:

I. Drooling burner.
II. Atomizer burner.
III. Chamber burner.
IV. Injector burner.
V. Projector burner.

These five classes are shown by diagram, fig. 58, in which each burner is pared down to its very simplest elements of construction, leaving out all unnecessary features of manufacture or detail which might be regarded as merely accessory.

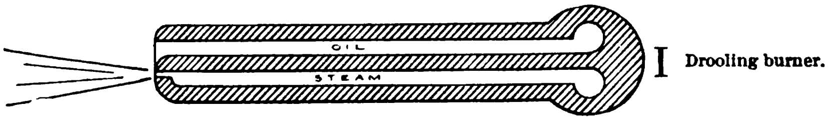


FIG. 59.

I. *Drooling burner.*—The name selected for this burner, while perhaps unusual, best expresses its function as seen from the diagram; the oil simply oozes out, or properly "drools" out, at the orifice over and on to the steam jet. In this case the drooling oil is simply carried away on a jet of flaring steam. The action is supposed to be as follows: As the steam issues forth it expands within the layer or film of oil which is being carried into the air of the fire box. It may be thought that this rather rough method of effecting vaporization would hardly be possible or satisfactory; yet as large numbers of these burners have been and are in actual use, they can not be regarded as crude or unsatisfactory.

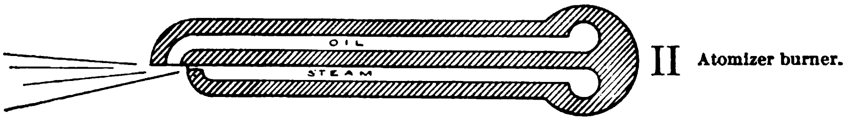


FIG. 60.

II. *The Atomizer burner.*—In this burner the oil is brought through an orifice from which it is swept off by a brush of steam or air. It is, in short, a principle made use of in an ordinary cologne sprayer. This form of spraying or atomizing is a very old invention, and its capabilities for spraying into a fine mist have long been appreciated.

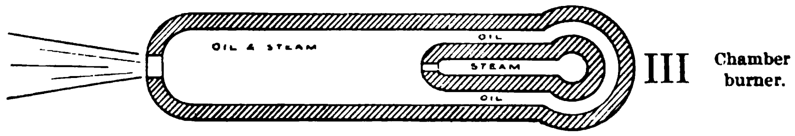


FIG. 61.

III. *Chamber burner.*—In this burner the oil and steam are more or less mingled within the body of the burner and pass out from the tip or nozzle as a mixture, and then, owing to the expansion of the steam, the oil is rapidly broken into minute particles. Burners of this type are simple in construction and have been carried through a large range of design.

IV. *Injector burner.*—Burners of this type are analogous to the injector often used for boiler feeding and similar purposes. Here the steam and oil rising, each through its own passage, mingle within cone-shaped passages, and as a mixture passes through a contracted nozzle, and then outward through a reversed flaring cone. Burners designed on these lines have the principle common to injectors in general, that they can draw or suck the oil to them and force the mixture of steam and oil outward at considerable velocity. Burners of this type have been in use for forty years or more on the railroads of Russia and have become with that nation what might be regarded as a standard type.

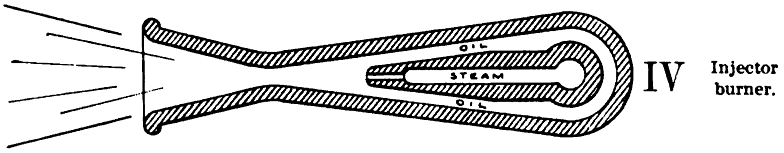


FIG. 62.

V. *Projector burners.*—In burners of this type the oil is pumped to the oil orifice and from there is caught by a passing gust of steam and blown off. This might be regarded as a subclassification of No. II, the atomizer burner, except for the fact that the brush of steam is located some distance from the oil orifice, and this sweeping brush of steam, as usually constructed, is arranged to entrain a certain amount of air further to aid in spraying and in combustion.

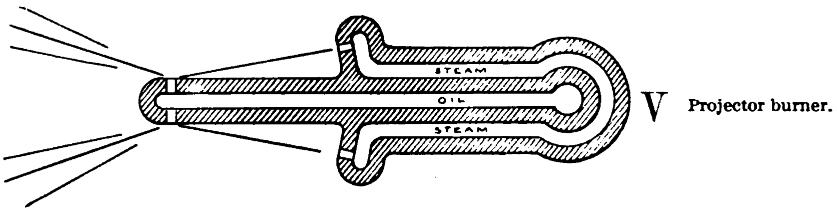


FIG. 63.

STRUCTURAL FORMS OF THE DROOLING BURNER.

The tips of each of these burners in each class can be specially modified, and will be later on treated under the subject of the forms of orificial spraying.

These five basic classes of burners will develop mechanically into certain structural forms, which structural or mechanical forms can likewise be arranged in four or five consecutive and related groups. The methods by which the various constructions have been developed from each class can be shown in the following diagrams: These forms,

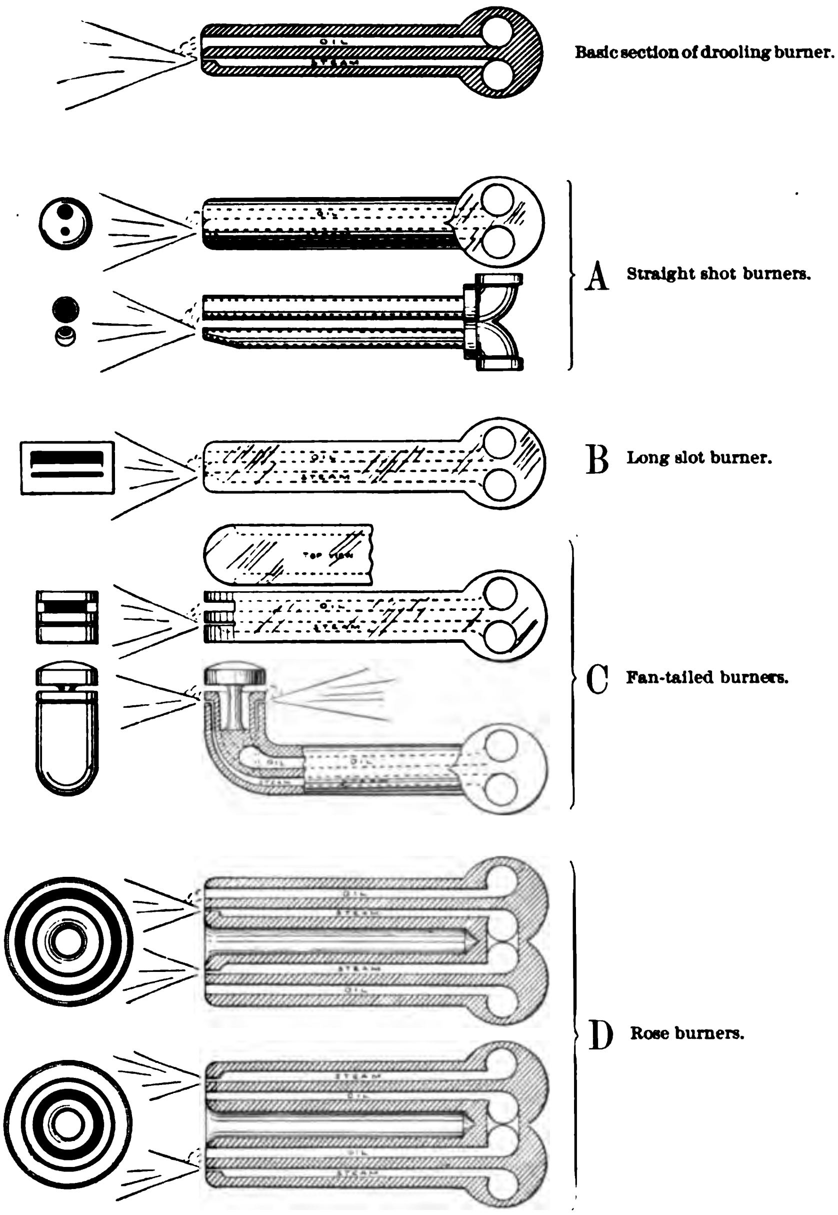


FIG. 64.—Possible modifications of the drooling burner.

in turn, may be subdivided into groups, due to changes in details or to further refinements. By changing the pressure of the atomizing medium or by some slight variation of construction a long or short flame may be produced, and such character of the flame may be of special advantage for particular purposes. For certain manufacturing purposes or for the melting of refractory metals the flame required may be quite different from that requisite for purposes of combustion, and therefore simple modifications in the form of the burner may be productive of far-reaching results.

As a possible study of the modifications of the drooling burner, reference is made to fig. 64. The first sketch shows the basic form of the drooling burner. This subdivides into four special classes designated as A, B, C, and D.

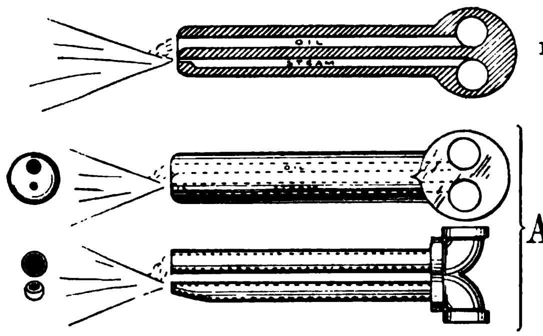


FIG. 65.

In form A is shown the drooling burner made in its simplest possible form, the upper view showing simply two drilled holes, the larger for oil and the smaller for steam, while the lower view shows two pipes in a double T elbow, the larger pipe being for oil and the smaller for steam. Burners have often been made in this exceedingly elementary form, and will give results without any further recourse to mechanism. For convenience we will term this subdivision A, as "straight shot burners," due to the fact that the flame formed will have considerable length.

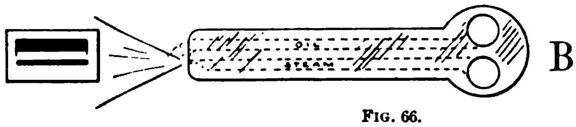


FIG. 66.

In form B the basic section of the drooling burner is developed into a class which gives two long slots. In this form a large number of burners have been constructed, and in another part of this report results of tests are given on the Santa Fe burner, which has been largely used on a railroad of that name. In this simple form of a box-shaped casting these burners have gained a wide use, especially for railroad work. The construction is of course crude, but the results from a practical standpoint have been quite satisfactory, due to the fact that there are no complicated parts, and it is almost impossible to choke up any of the openings even with quite a dirty oil. Where burners are required to use a very heavy oil or residuum, or even a tar, these burners will always operate. This form B, which, for convenience, has been termed the long-slot burner, can be developed into the additional form C, or a fan-tailed burner.

In form C there are two burners which can be devised. The first form, in which the fan-tailed effect spreads through but a small arc of a circle, and the second form, in which the fan-tailed effect is extended so as to cover the arc of the entire circle. The first form will cover a large amount of surface in a wide or square fire box, while with the second form the burner can be placed in the center of a grate and the flame will extend outward in the form of a continuous sheet and cover the entire fire box or grate area, such uses being desirable, for example, in the fire box of vertical boilers, such as fire engines, etc.

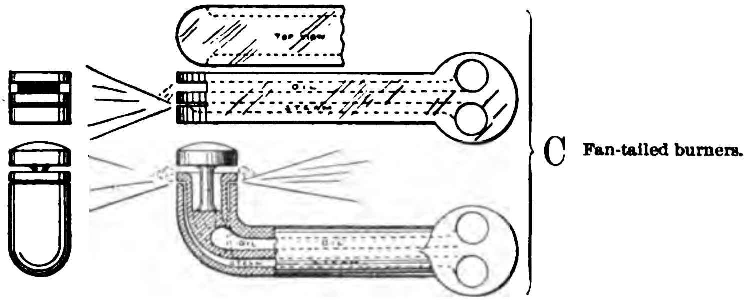


FIG. 67.

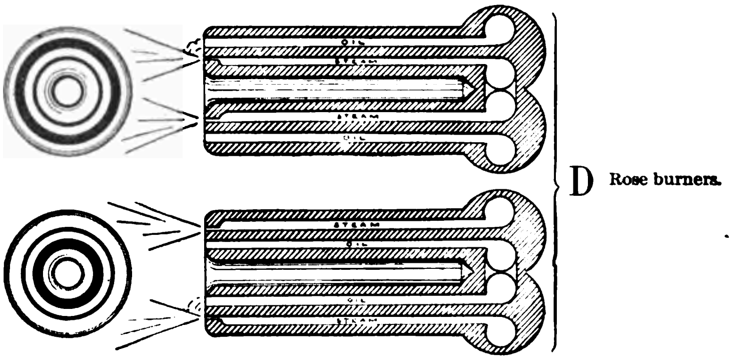


FIG. 68.

The last form or modification, or form D, can be developed from the basic section of this drooling burner by conceiving that the section is revolved around an axis parallel with the burner axis. By revolving the section around an axis on the steam side there will be derived a burner of the style shown in the upper part of the pair of form D, or by revolving the basic section around an axis near the oil side we get

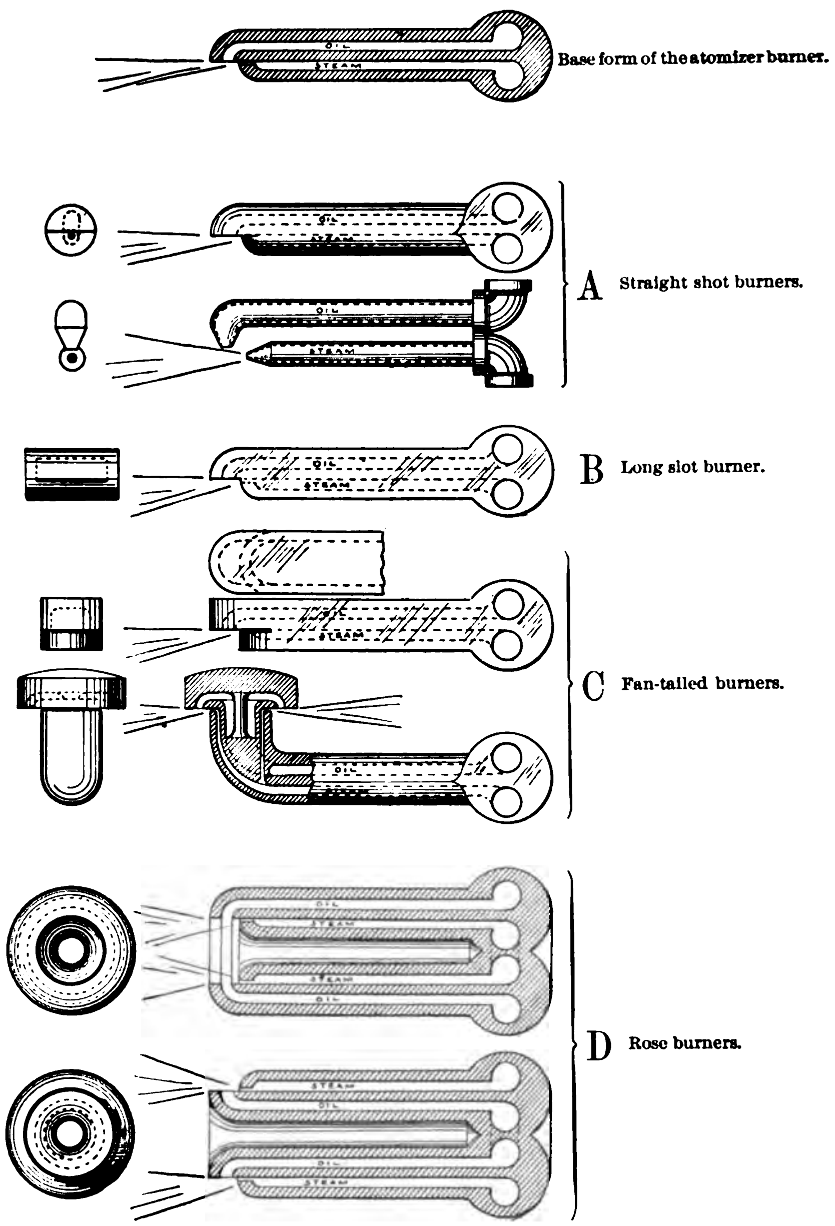


FIG. 69.—Possible modifications of the atomizer burner.

a form of burner shown as the lower one. Either of these two burners, while apparently very different in form from the basic section, yet are nothing more or less than a development of the original type. Burners of this style should probably only be used where very heavy consumption of oil is required. In heavy metallurgical operations, brick kilns, and where a large volume of flame is desired such burners have a wide field of usefulness.

POSSIBLE MODIFICATIONS OF CLASS II, ATOMIZER BURNERS.

These forms are as shown in fig. 69. At the top is shown the basic form of the atomizer burner. Then under form A, "straight-shot burners," are shown two modifications, one formed by round openings in a small cylindrical casting, while the other is formed of a double T elbow containing two pieces of pipe, one for oil and one for steam, the end of the oil pipe being hooked over, as shown. The latter construction will be at once recognized as the very earliest form of atomizer. Its simplicity and effectiveness as a spraying agent can hardly be questioned. A position of tips can also be arranged so that a certain amount of siphonage can be secured in the oil pipe, although this is a function not to be at all relied upon.

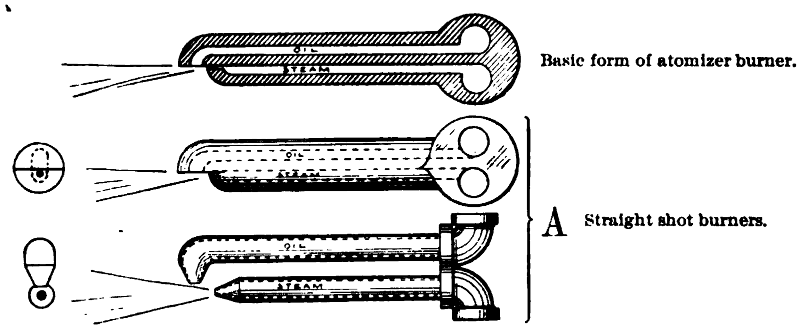


FIG. 70.

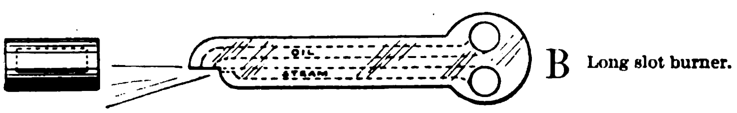


FIG. 71.

Form B shows the same basic section of atomizer expanded sideways to form the "long-slot burner." This style of burner is also made use of very largely in locomotive work on account of its great advantages of wide and open passages which do not readily clog up, and consequently need but little attention.

Form C shows two designs, also derivable from the previous form and the basic section, the upper of the two showing a fan-tailed effect through a portion of an arc of flame and the other a flame distributed around the whole circle—the latter style of probable service when placed in the center of grates of vertical boilers.

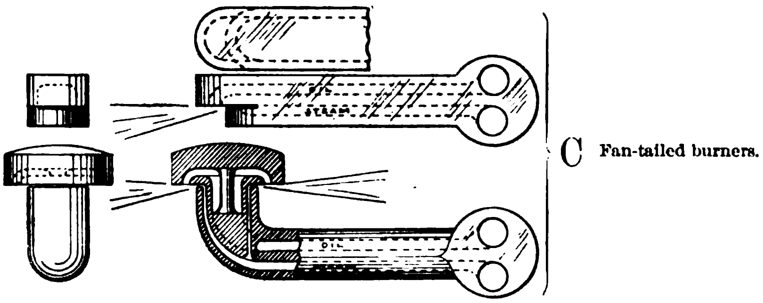


FIG. 72.

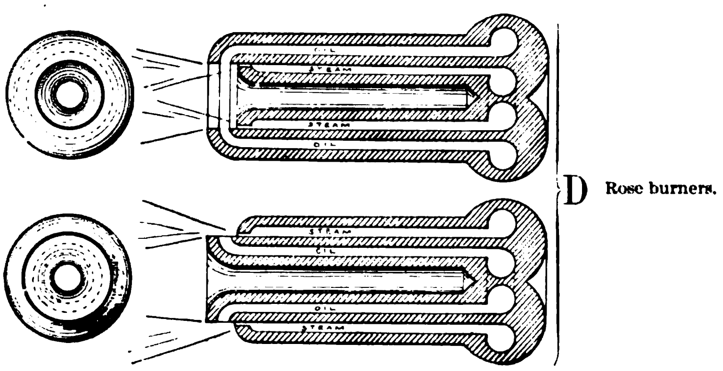


FIG. 73.

Form D, rose burners, shows the basic section revolved about an axis either on the oil side or the steam side. In the first case, while securing a satisfactory atomization of oil, there would be obtained the effect of more or less of a straight-shot burner, while the latter form of rose burner would afford more of a flaring effect.

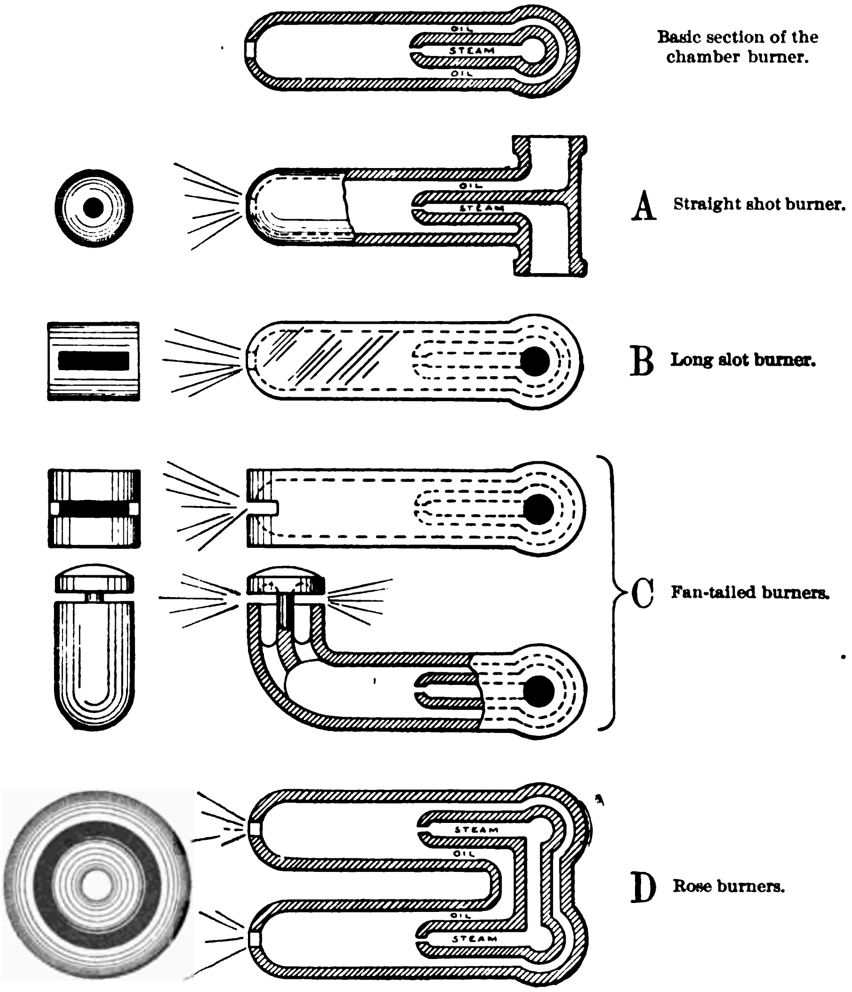
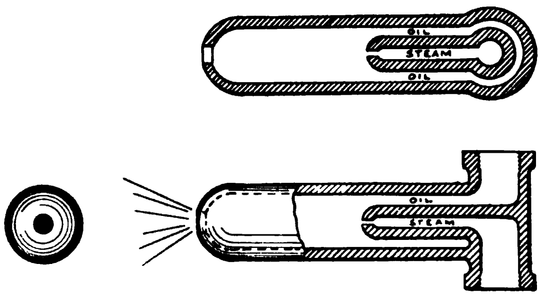


FIG. 74.—Possible modifications of the chamber burner.

POSSIBLE MODIFICATIONS OF CLASS III, CHAMBER BURNERS.

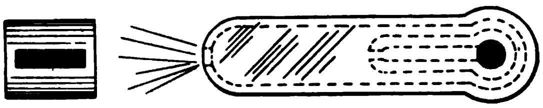
These forms are shown in fig. 74. At the top is represented the basic form of the chamber burner. Then under form A is shown the simplest modifications formed by round openings in a small cylindrical casting. Here the oil and steam, each coming from their proper side of the burner, mingle in the end chamber of the burner and are ejected outward from the round orifice. It will also be observed that with this form of burner no siphonage is possible, and, in fact, if the orifices are not properly proportioned the pressure of steam may drive the oil backward to the pump.



Basic section of the chamber burner.

A Straight shot burner.

FIG. 75.

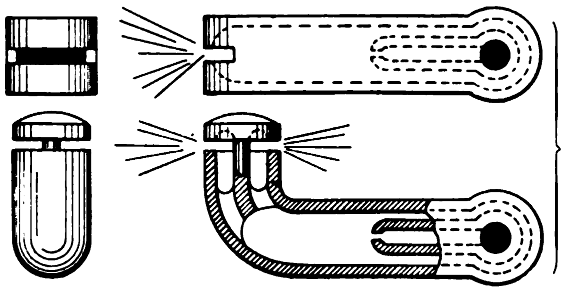


B Long slot burner.

FIG. 76.

Form B shows the same basic section of the chamber burner expanded sideways to form the long slot burner. As thus constructed, this style of burner is made use of very largely in locomotive work, on account of the advantages of large passages, which do not readily clog up, and consequently the attention demanded by the locomotive fireman is a minimum.

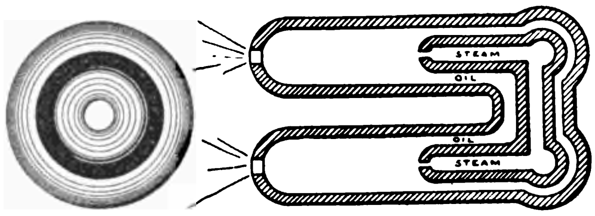
Form C shows two designs also derivable from the previous one and from the basic section. The upper burner of the two indicates a fan-tailed burner forming a spread of flame through a portion of an arc of a circle, and the other burner produces a flame distributed in a fan or rose shape around the whole circle. The latter style would be of service when placed in the center of grates of vertical boilers.



C Fan-tailed burners.

FIG. 77.

Form D, rose burners, shows the basic section revolved about an axis, thus forming a burner possessing an annular orifice affording a burner of very large spraying capacity, which, as with other types of burners of this rose form, are specially suitable for furnaces of large capacity or useful in smelting operations.



D Rose burners.

FIG. 78.

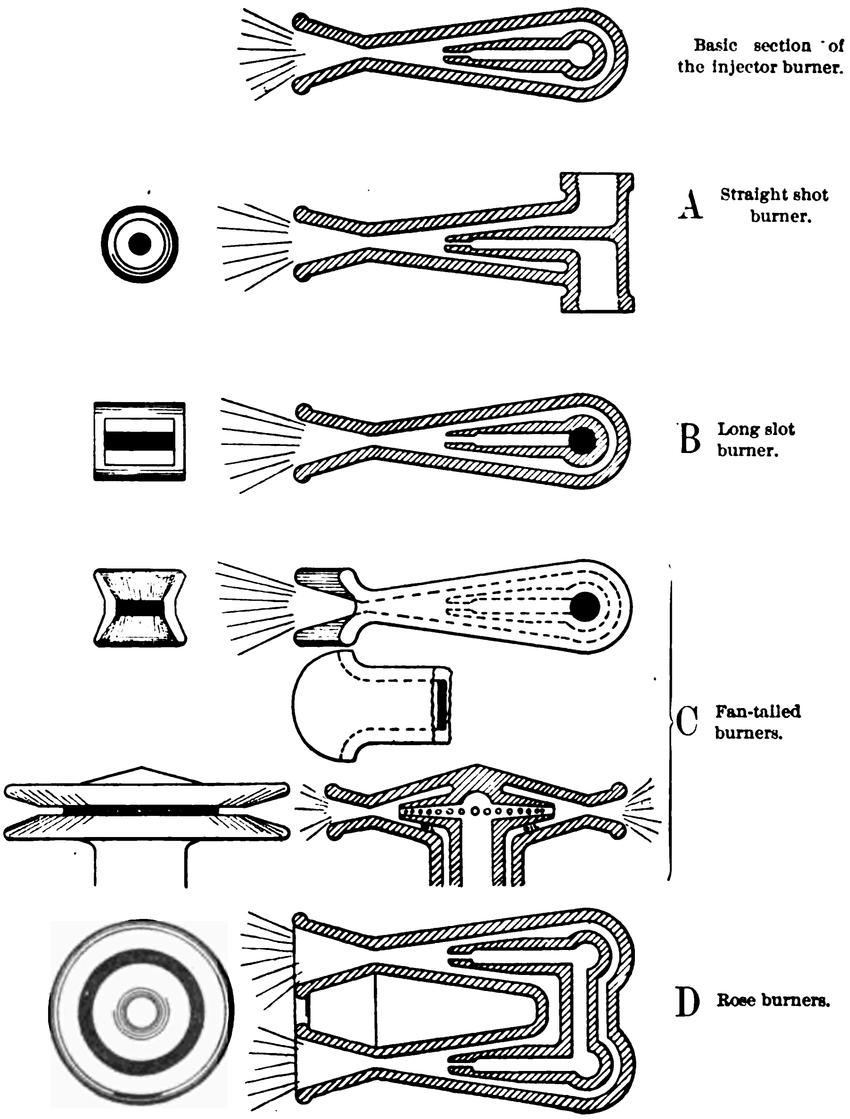


FIG. 79.—Possible modifications of the injector burner.

POSSIBLE MODIFICATIONS OF CLASS IV, INJECTOR BURNERS.

These forms are as shown in fig. 79. At the top is represented the basic form of the injector burner. Then under form A is shown the simplest structural arrangement which can be devised, which consists, essentially, of a nozzle placed behind another tapering nozzle or throated opening. This is essentially a crude design of any steam injector, and, like all injectors, has the property of sucking a fluid to it under the operation of the rapidly passing steam or gas through either of the nozzles. In form A, as shown, the openings are, as usually made, of a circular cross section.

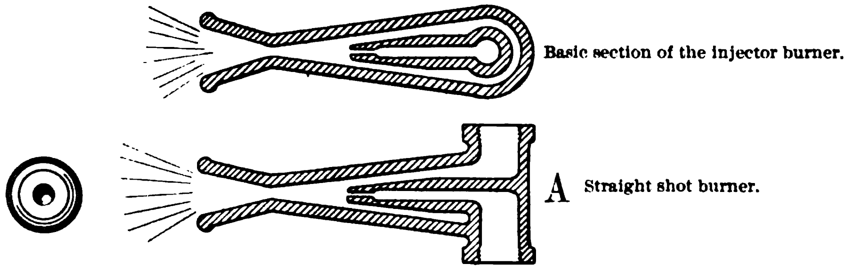


Fig. 80.

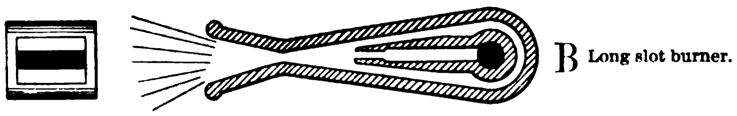


Fig. 81.

Form B represents again the same basic section of the injector, but the orifices are extended sideways to form a slot-shaped opening. By this means its capacity as a burner or injector is greatly enhanced. Where it is desirable to use one large burner instead of the number of small ones, this form of slotted injector will give the required capacity.

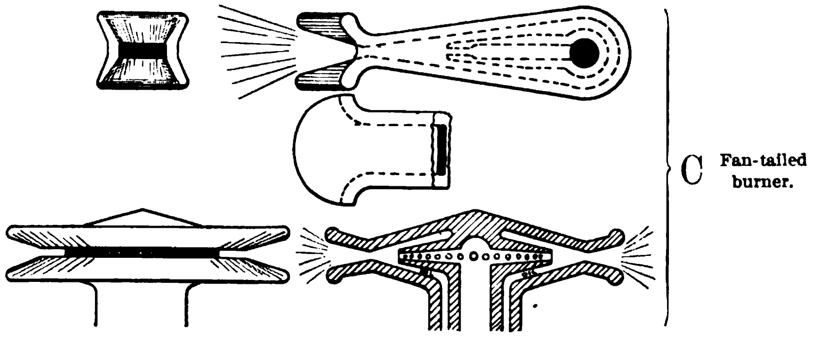


Fig. 82.

In form C is shown again the injector burner designed with its mouth or slotted opening in a flaring shape, thus greatly increasing the horizontal distribution of the resulting jet of spray. By this means is thus secured a fan-shaped flame. This fan-tailed effect can be increased so as to extend through a complete circle, and this will result from the burner being conceived to be revolved about a vertical axis, as shown in the lower portion of the figures of form C. This mushroom-shaped burner would probably prove available for installation in the center of large square or round fire boxes of vertical boilers.

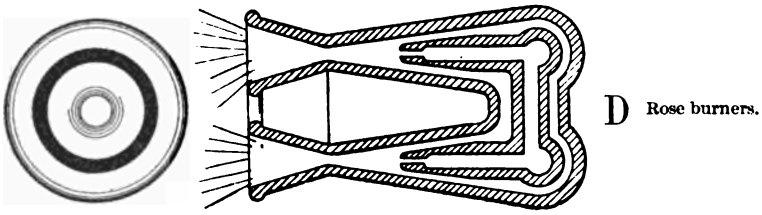


FIG. 83.

Form D represents again the injector burner, but the basic form is this time conceived to be revolved about an axis parallel with its center line. The resulting design will afford a burner of very large capacity, suited only for heavy smelting operations.

Types of injector burners of various styles came into very early use in the art of oil burning and still remain a standard device in many large installations. Many of these have been in use for thirty or forty years alone in the regions of the Russian oil fields, and are still mainly employed on the oil-burning railroads of southern Russia and the Caspian region. The type of injector burner is often called the Urquhart burner, as Mr. Urquhart, now superintendent of motive power of the Trans-Siberian Railway, was the first to make its design successful and to keep it constantly in use as a successful locomotive appliance.

In fig. 84 is shown a form of Urquhart injector burner designed by Dr. C. B. Dudley, superintendent of tests of the Pennsylvania Railway, on his return from Europe, where he had been sent by his railroad to investigate the use of oil on Russian locomotives. The design as shown in the figure represents essentially the full Urquhart details, except that certain facilities in the way of gearing were added to give a delicate adjustment to the position of the coned nozzles. It was understood that these burners were successful on the Pennsylvania Railway, but the price of oil being so great in comparison with coal, the employment of oil as a locomotive fuel became prohibitive from financial reasons alone.

In fig. 85 is shown another and simpler form of injector burner which was designed by the Herreshoff Manufacturing Company, of Providence, R. I., for use under the boilers of the U. S. torpedo boats

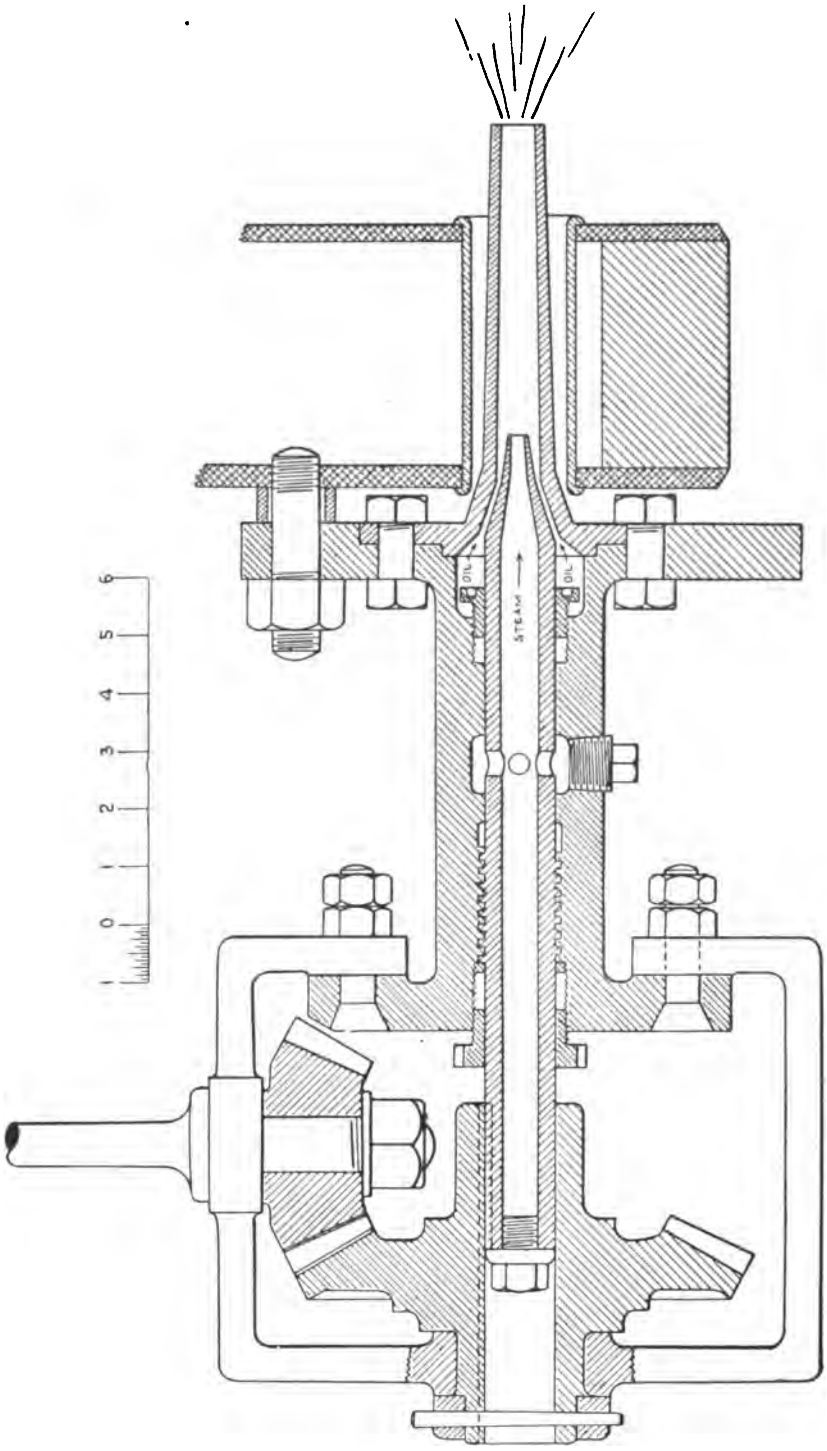


FIG. 84.—Fuel-oil burner, Pennsylvania Railroad.

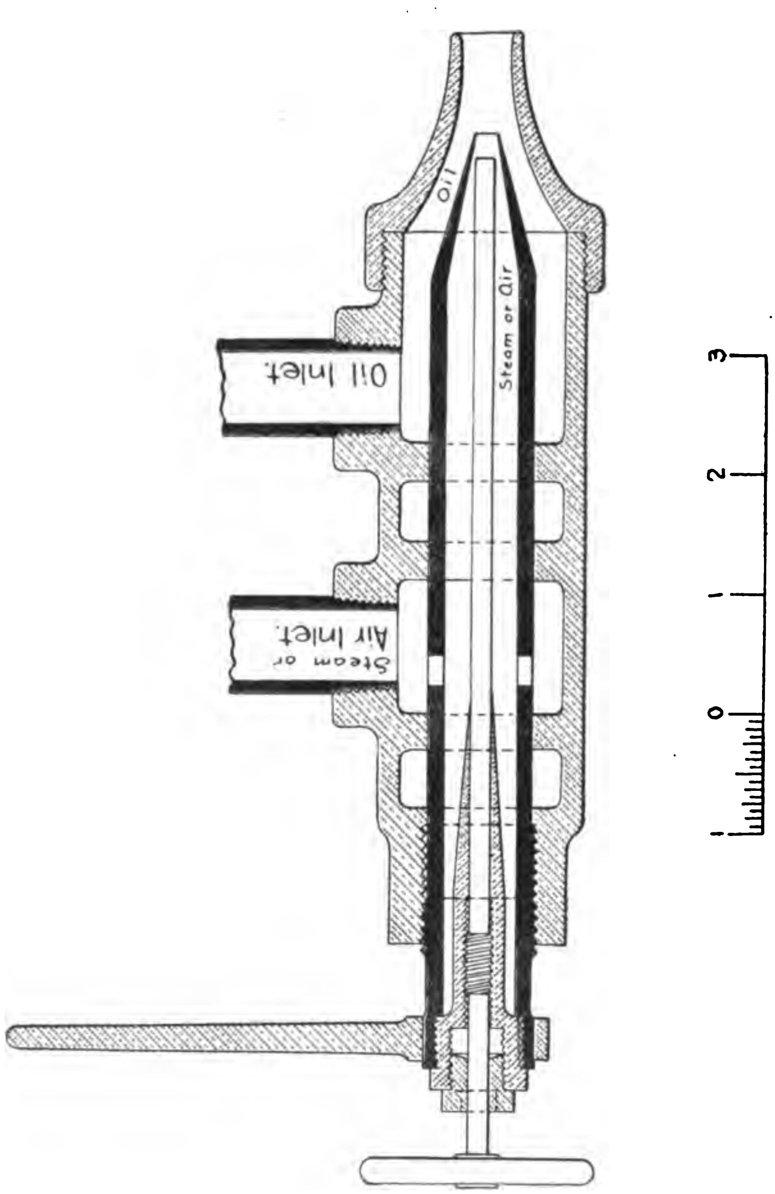


FIG. 85.—Oil burner by Herreshoff Mfg. Co. for U. S. S. *Talbot* and *Gwin*.

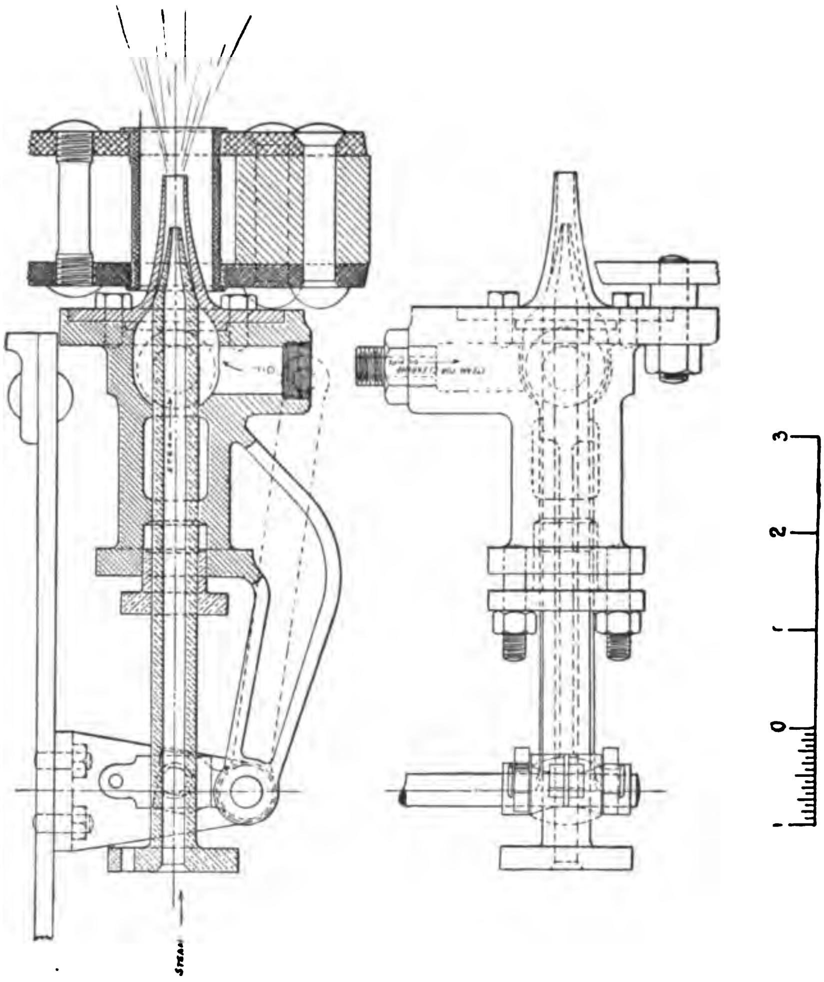


FIG. 86.—Russian locomotive burner. (Ourgard.)

Talbot and *Gwin.* In experimental work these burners gave considerable satisfaction.

In fig. 86 is shown a Russian locomotive burner (Ourgard) which is at present largely used for the service of locomotives in that country. Its refinement over previous burners is simply due to the fact that there is a little more quickness of action in closing or opening the oil supply by movements of the inner nozzle.

Before dismissing the subject of injector burners it should be said that although they have the great advantage of supplying a suction power, both for drawing in their oil or to draw in an air blast, which tends to increase their efficiency, yet it must be said that, in addition, they have the one great serious fault that they are the most noisy burners made. To install them in stationary plants or in enclosed firerooms is almost out of the question, as the noise and roar which they create is continuous, deafening, and distressing, and few firemen can be found who are willing to stand regular watch in such continued racket. In locomotive work, as the burners are located, usually, outside of the cab, and as the locomotive makes a thousand other noises in addition to the burners, a little supplementary noise is apparently absorbed in the general clatter.

Again, most of these burners being designed on the lines of the expanding nozzle, cause, in themselves, a great increase in velocity of the outgoing jet, with the result that the flame is usually one of great force and very long in extent, in proportion to the burner. The long flames might be desirable in the long furnaces of certain land boilers, but where used in the contracted fire boxes of marine and locomotive boilers the furnace design requires very serious attention, to permit of the proper upkeep of the brickwork, arches, and baffling.

ORIFICIAL SPRAYING.

The classes of burners previously shown were the fundamental skeletons on which actual burners are constructed. Most of these burners can be further modified by special design of their tips or orifices, thus leading to still greater variety and often to greater improvement in their spraying qualities. These modifications of tips have been reduced to a series of classes which should be independent, as near as may be, of the other possible mechanical arrangements of the burners. As a study for the various methods of orificial spraying, the following styles of tips were considered, as shown in fig. 87, and under any form of these tips it is found that any type of oil burner could be classed.

Form I: The design of the tip is in itself a matter of much moment, as the configuration of the tip edges has a very important physical

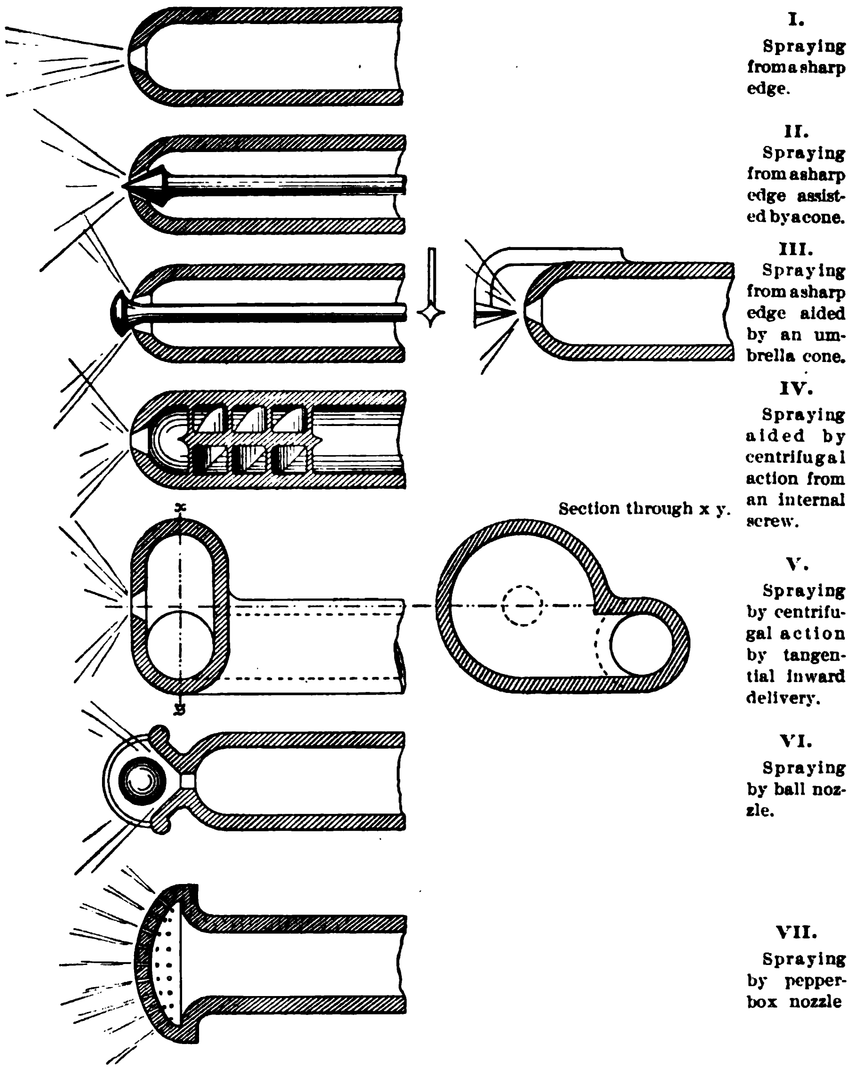
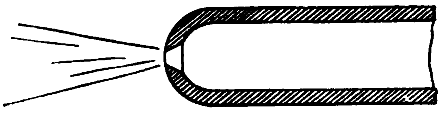

I.
Spraying from a sharp edge.
II.
Spraying from a sharp edge assisted by a cone.
III.
Spraying from a sharp edge aided by an umbrella cone.
IV.
Spraying aided by centrifugal action from an internal screw.
Section through x y.
x
y
V.
Spraying by centrifugal action by tangential inward delivery.
VI.
Spraying by ball nozzle.
VII.
Spraying by pepper-box nozzle

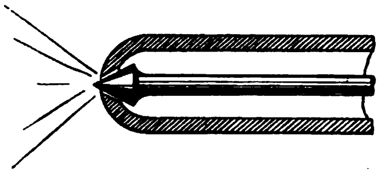
FIG. 87.—Orificial spraying. Forms of tips by means of which spraying may be effected.

effect on the formation of the spray, and whether the material which it is intended to spray is forced through by steam, compressed air, or even by the effect of its own pressure supplied by a pump, the edge over which the spray last passes has a determining effect on the state of subdivision of the spray. In form I is represented an ordinary nozzle with a sharpened edge at the point of exit. If a proper angle is selected for this edge, and the edge itself is well sharpened, the outgoing stream instead of passing out in a straight line, as from a hose nozzle, is caused to diverge, and if divergence ensues, of course there follows an expansion in the volume of the outgoing liquid which causes a condition of more or less subdivision of the particles of the fluid.



I Spraying from a sharp edge.

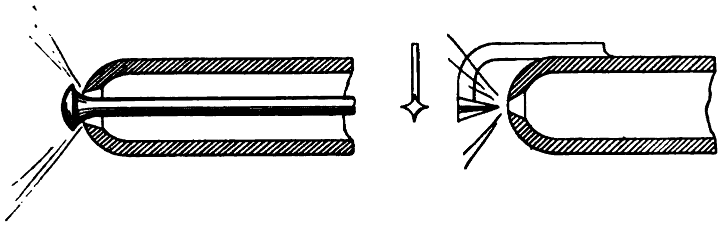
Fig. 88.



II Spraying from a sharp edge assisted by a cone.

Fig. 89.

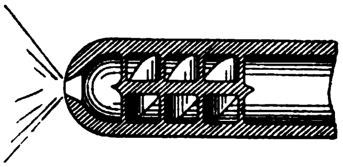
In form II is shown a design of orifice in which this effect is heightened by introducing a cone in the center of the conical orifice. The physical reason why this increased divergence is secured is due to the fact that the cone takes the place of any streams of oil which in the first case had the tendency to travel in the straight lines of the solid core of fluid. All the lines of fluid traveling down the cone surface meet in collision at the edge and tip of the cone and rapidly expand owing to the pressure which was behind them.



III Spraying from a sharp edge aided by an umbrella cone.

Fig. 90.

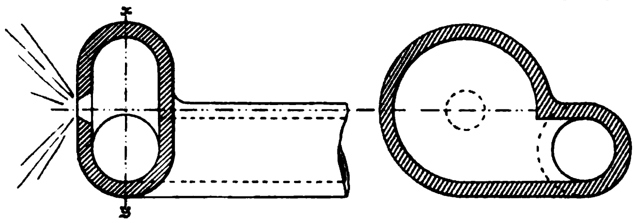
In form III there is again indicated the same type of sharpened cone-shaped orifice, but outside of this is placed a diverging cone upon which the outgoing spray strikes and receives a greater amount of divergence than the orifice edges would alone have produced. This diverging cone is usually placed with its stem extending within the orifice, although at the right of the diagram is shown a case where the diverging cone is supported from the outside. The amount of divergence effected by this cone can be controlled to any extent by the position or shape of the diverging surface of the cone.



IV Spraying aided by centrifugal action from internal screw.

FIG. 91.

In form IV there is shown an orifice similar to form I, but increased divergence of the cone of spray is obtained by circulating the fluid in a rotary manner before issuing from the sharpened orifice, the physical result of which is that as soon as the fluid leaves the orifice the effect of centrifugal action is manifested to fling the oil tangentially outward to some distance. In the diagram, as shown, this centrifugal effect is obtained by passing the fluid through spiral passages.

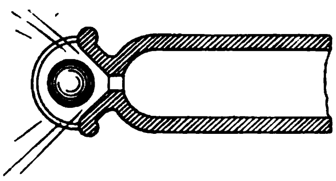


Section through x y.

V Spraying by centrifugal actoin by tangential inward delivery.

FIG. 92.

Form V represents the original style of orifice, but the casing is so shaped as to obtain the rotational effect of the previous tip by admitting the fluid tangentially to the interior of the chamber. The effect on the resulting cone or spray is the same as in the previous example.



VI Spraying by ball nozzle.

FIG. 93.

Form VI: The type of nozzle is changed by inserting a ball in the outgoing current of spray, thus mechanically breaking up the action by requiring the spray to strike the ball, this being nothing more or less than the old familiar type of the dancing ball, long made familiar in water nozzles and pneumatic nozzles as a curiosity. Its effectiveness as a spraying agent is probably no greater or as great as a well-designed and proportioned orifice of form III.

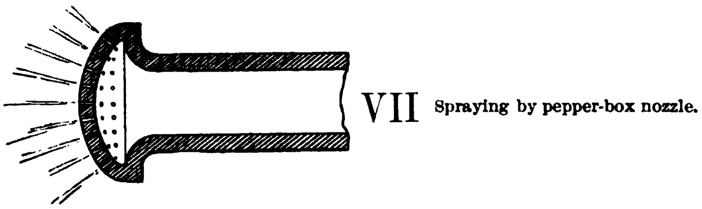


FIG. 94.

Form VII represents a class widely different from any of the preceding, which for lack of any other properly designative term might be called the "pepper-box nozzle." Its effectiveness for a certain class of burners may be made very great, but it always suffers under the great disadvantage of a multitude of small holes, which are exceedingly liable to become choked up by foreign matter or by the hydrocarbons formed at the tip of a burner while in action.

NONSUCCESS OF APPARATUS DEPENDING ON GASIFICATION OF OIL.

The impossibility of successfully operating burners designed on the principle of superheating the oil to a point bordering on gasification has been both theoretically and practically demonstrated. The conclusions as expressed by Engineer in Chief Isherwood in regard to the liquid-fuel experiments conducted over thirty years ago by a board of naval engineers as to the impossibility of converting liquid fuel into a gas within the burner itself hold as true now, in the light of later experiment and practice, as they were then. In regard to such burners Commodore Isherwood thus reported:

> The experiments in question embrace those made with Colonel Foote's apparatus at the Charlestown Navy-Yard, and those made with other apparatus on different boilers in the New York Navy-Yard, all of them, I believe, of considerable value, but never reported in full, with the exception of one made about ten years ago and which is now on the files of the Bureau of Steam Engineering. In every case the patentees abandoned the trials before they were completed, owing to the failure of their apparatus.
>
> The liquid oil has, in all cases, to be transformed into oil gas before it can be burned. This transformation can be made by the direct application externally of heat to the liquid, but the temperature of the oil on the vaporizing surface is higher than the temperature required to decompose it, the result being deposition of solid carbon in the form of coke, which soon fills the vaporizing vessels and renders them useless. This coke is frequently so hard that cold chisels can scarcely detach it, and if thrown into a fire even in small fragments it burns with excessive slowness, like graphite. Whenever the vaporizing vessel is subjected to a high temperature, like that of a boiler furnace, the decomposition of the oil and decomposition of coke go rapidly on, so that in the course of a few hours any vessel of practicable size is filled by it. All apparatus exposed to anything like furnace or flame temperature will inevitably fail from these causes in the future, as they have in the past. To make trials with such devices will merely serve to confirm this fact. The smaller the vaporization vessel and the higher the temperature to which it is exposed the more quickly will it fail.
>
> A very large variety of apparatus has been invented, embodying substantially this principle or mode of direct vaporization of the oil, the only difference being unimportant variations of detail to render the inventions patentable, and in all cases the vaporizing vessel has been necessarily small in order that the pressure heat could be employed in the oil vaporization, and the highest possible temperature was used in order that a sufficient quantity of the oil might be vaporized in a given time. None of the apparatus when pushed to the maximum will last more than half a dozen hours.
>
> It is quite possible, however, to vaporize the oil by the indirect application of heat by means of steam or water intervention, so that the temperature of the vaporizing surfaces will be below the temperature of decomposition of the oil. This would be manufacturing oil gas in a costly manner, and the gas could afterwards be burned in jets in a furnace like illuminating gas, but it would not be "burning petroleum," or any oil, in the proper sense. The vaporizing apparatus to produce the requisite

quantity of gas per hour for any considerable power would have to be enormously bulky, heavy, and expensive—in fact, a complete gas-making plant itself; and I do not believe after the gas is obtained that a sufficient quantity of it could be consumed per hour by any practicable arrangement of jets in a furnace to produce as much heat as could be obtained from coal burned at the maximum in the same furnace.

The only method that has been attended with any success is that of "atomizing" or spraying the oil, by means of steam under sufficient pressure for the purpose, used in an injector, placed outside the furnace so as not to receive the high temperature of combustion. The oil in fine spray, excessively comminuted, is thus squirted into the furnace, where it is decomposed at large and its constituents separately consumed. An ordinary Giffard injector is employed, and the smaller its nozzle the better it works. Even in this case, however, the injector will fill with coke after a considerable time and requires to be unscrewed from its pipe and cleaned out, another being substituted meanwhile. In this manner oil fuel can be satisfactorily burned. All other methods have failed.

NECESSITY OF OFFICIALLY INSTALLING ALL AUXILIARY APPLIANCES.

Strainers.—The majority of the crude oils having been obtained from wells driven into the earth, of necessity carry in the body of the oil, more or less intimately mixed, certain small proportions of water, as well as more or less sand or grit. The heavier and more viscous the oil, the greater the tendency there is to hold in suspension these deleterious substances. Large proportions of these foreign matters separate out while the oil is stored in the producers' tanks, but when the oil is hurried to a market the dealers are not always as careful as they might be to extract these harmful substances.

In general it can be assumed that no crude oil is perfectly clean. Therefore in the installation of any oil-burning plant special provision should be made for straining out all sand and foreign matter. Arrangements should always be provided for catching the water as it slowly settles to the bottom of the tanks or bunkers.

The effect of sand in oil increases the wear on the small annular nozzles of the oil burner, or, when using burners provided with specially small orifices, these openings may become altogether clogged.

Various types of strainers for oil have been devised, some of which are simply formed by the insertion of a blind, wire-gauze gasket in the joints of the oil pipe. This device, while having the merit of simplicity, yet proves as a working method to be unsuitable, owing to the long time required to unbolt the joints to take the gauze out for cleaning. A much more satisfactory plan is to employ appliances devised on the lines of strainers used in other classes of marine work, such as Macomb strainers, etc. A strainer of this type, as designed by the board, is shown in fig. 95. An advantage of this type of construction is that the wire gauze is placed on the inside of a perforated metal basket. This metal basket is of such shape that it can be readily removed by giving it a slight twist and releasing it from the lugs which hold it in place, and the basket can be then removed through the top of the strainer casting, which is fitted by a cap, kept in position by two handles or ears which are formed on the cap top. As thus shown the whole operation of taking out the strainer can be done by hand, without recourse to tools or wrenches. The strainer basket, once removed, can be replaced by a fresh and clean one.

The gauze used for oil strainers should not be too open, and should be formed of brass wires of probably a width of mesh work equal to about half of the width of oil orifice in the burner.

Another form of strainer is as represented in fig. 96, which has been largely used in the European work undertaken with the Korting mechanical burner. As the oil orifice in those burners is only about one-sixteenth of an inch in diameter, it is therefore of utmost importance that the oil be carefully strained through very fine mesh work. In the plan as shown the wire gauze is placed around a perforated cylinder, and the oil is forced from the outside of the cylinder through the mesh work, then into the perforated cylinder, and to its outlet. This type of strainer is also generally provided with an oil warmer, for as we have seen, with very viscous oils it is often desirable to give them a moderate heating in order to increase the fluidity.

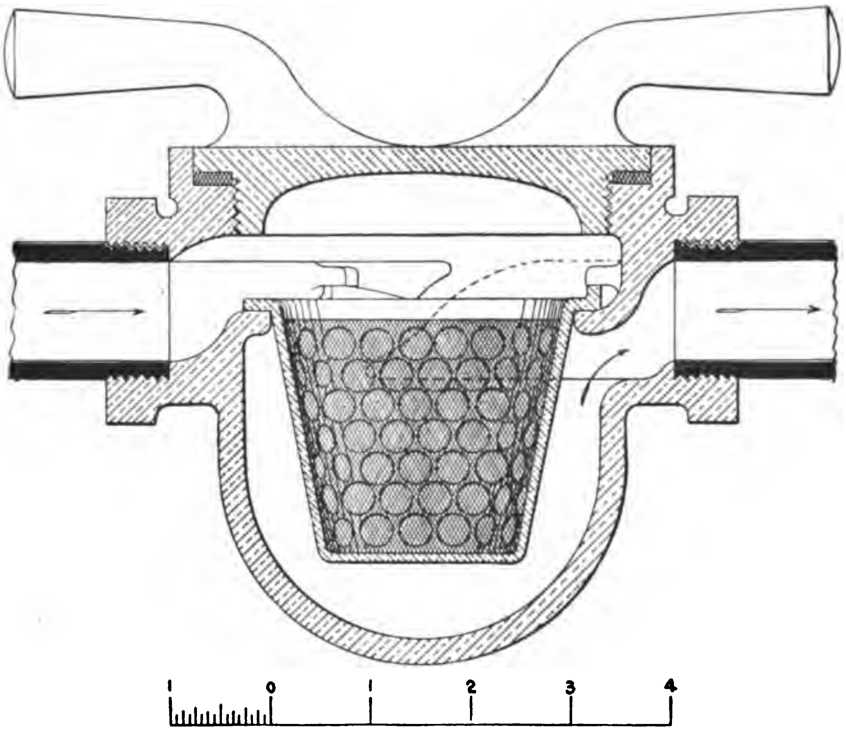


FIG. 95.—Oil strainer for heavy oils.

In this filter-heating device an internal steam jacket is provided through which either light pressure live steam or preferably exhaust steam from any of the auxiliary pumps can be passed.

In the placing of these strainers it is not unusual to find a strainer placed on the oil pipe on each side of the pump, thus insuring that no grit gets into the pump, and that any particles of old packing or other material from the pump can not go to the burner through the last filter. A still more desirable plan is to have two strainers between the pump and the burners, so that when one filter is being opened the current of oil can be transferred by means of a by-pass valve through the other filter.

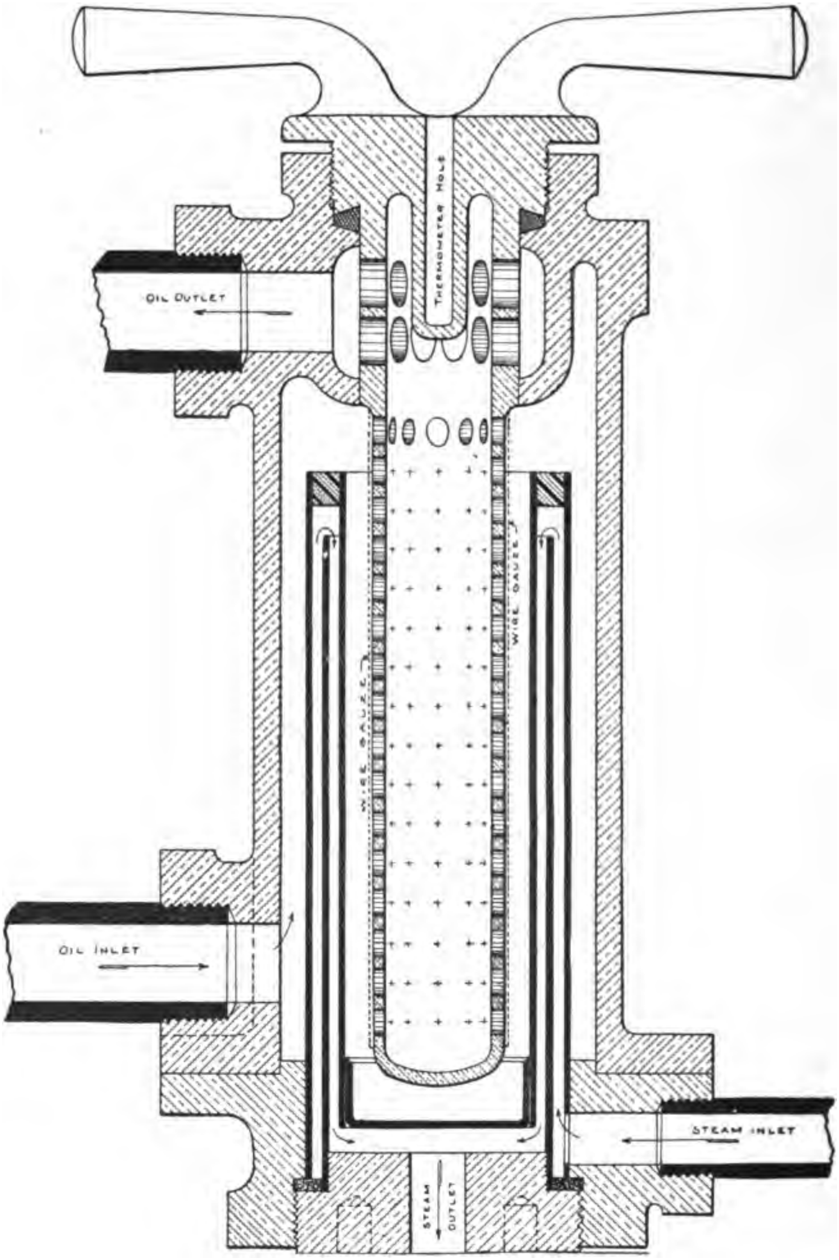


FIG. 96.—Strainer for oil, with oil-warming device.

SEPARATION OF WATER.

There is no practicable device that will directly separate the water from the oil. This separation can only be satisfactorily effected by allowing the water to settle to the bottom of the tanks by gravity. It therefore follows that if the suction to the oil pumps are placed in the bottom of the tanks, water will be often drawn when only oil is desired. A thread of water blown into the oil burner effectually extinguishes the flame in the furnace, and if oil does not soon follow the water, there may be difficulty in relighting without introducing an outside flame. In order to insure a supply of oil from the tank without an admixture of water, devices have been adopted whereby the oil-suction pipe is caused to swing up or down in the oil bunker to a level at which it is known that pure oil can always be obtained.

Fig. 97 shows a practicable design used in English tank steamers in which this movable oil-suction pipe is carried by a float. The suction tip is thus always maintained at a point within a few inches of the top of the oil wherever the oil level in the tank may be at the time. It will also be seen that the tip of the oil-suction pipe is surrounded by a steam heating coil, the object of which is to slightly heat the oil in proximity to the inlet, thus increasing the fluidity of the oil, so that even in cold weather the oil may be readily pumped.

At the bottom of each bunker there should always be provided a water cock or blow-off for the purpose of blowing off any water which may be found to have settled in the tank or compartment.

HEATERS FOR OIL.

Certain crude oils at the ordinary temperature of the atmosphere are of great viscosity, which viscosity increases as the temperature gets lower. At 30° to 40° F., which is not an unusual outdoor temperature, the fluidity of the oil is so slight that it is almost impossible to pump the oil or to force it to the burner. It is therefore necessary where fuel oil is to be used in regions which are subjected to severe winter temperatures that there should be means for heating the oil so that the oil may more readily flow to the pumps. The usual manner of accomplishing this is not to attempt to heat the whole tank or bunker of oil, but simply to heat the oil immediately surrounding the suction pipe to the pumps. This can be easily accomplished by placing a coil of a few turns of steam pipe about the suction pipe. This method is also shown practically accomplished in the previous fig. 97, where this heating coil was attached to the floated pipe.

In all pipes intended for the transmission of crude oil it is desirable that connections should be made to them so that steam can be turned into the pipes after shutting off the oil. These pipes can be thus cleaned by the heat and the force of the blowing steam, and any deposited

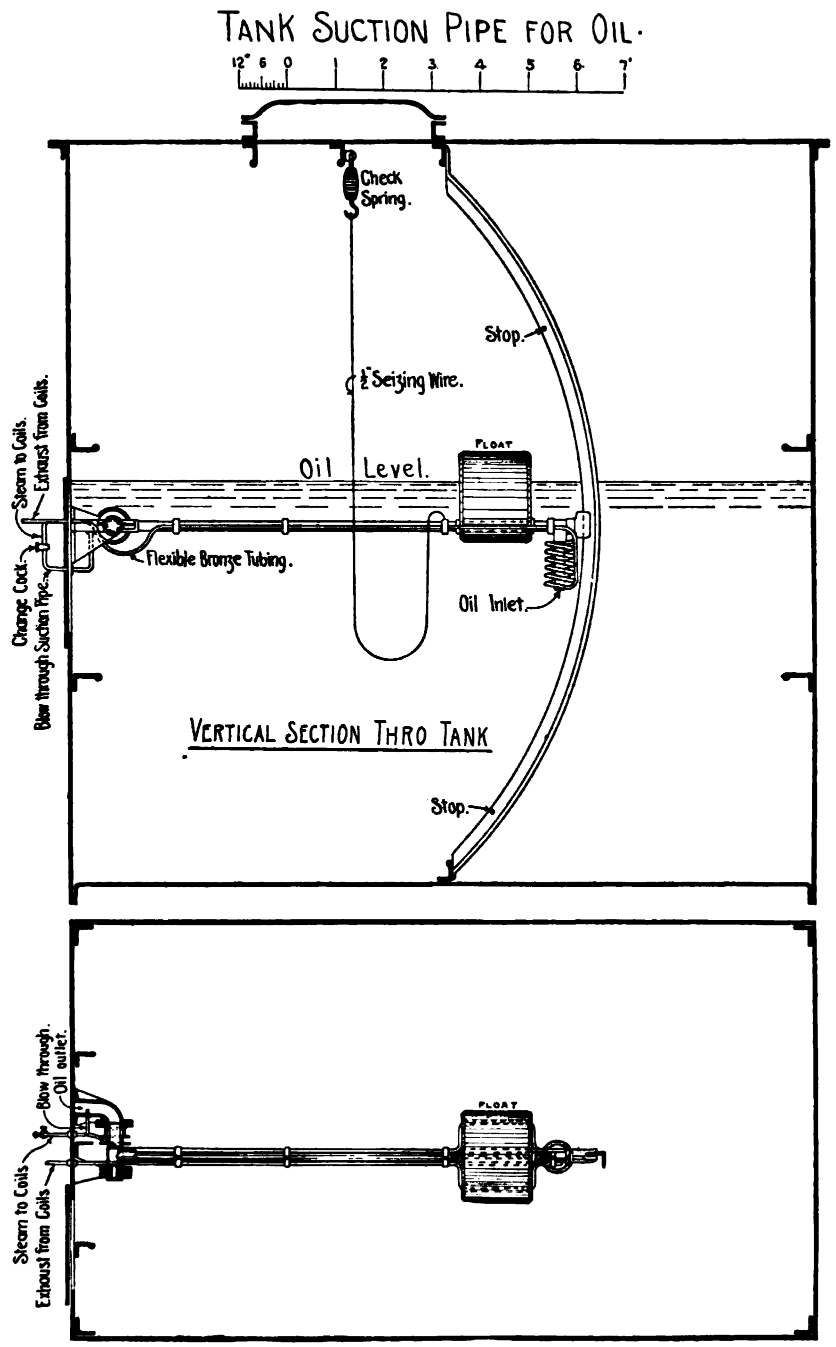


FIG. 97.—Device for taking oil near top of variable oil surface; instead of taking oil out of fixed outlet at tank bottom, with resulting possibility of obtaining water instead of oil.

asphalts, paraffins, or condensed hydrocarbons can be cleared out before the pipes become choked so as to impair their efficiency.

The heating of the oil should be always recommended as an aid to secure better operation of pumps and burners, but, as shown elsewhere in this report, this heating should never be carried to such a degree of temperature as will cause decomposition of the hydrocarbons of the oil. The degree of temperature at which such decomposition is likely to occur has been ascertained for the oils of each region.

FEED TANKS FOR BURNERS.

Many installations for oil burners use a secondary feed tank between the main bunkers and the pump. This tank is designed with the intention of holding an easily measured quantity of oil, and the number of times it is filled and emptied indicates a convenient method of measuring the total number of gallons or barrels used in a stated time. This feed tank is often provided with heating coils, and the temperature is always kept at a figure just short of the depositing point of the hydrocarbons.

OIL-PRESSURE REGULATORS.

With most burners it is desirable that a uniform pressure should be maintained on the oil circuit to the burner. If it were possible to keep the pumps automatically and perfectly regulated, a uniform pressure could be secured. There are many devices on the market which set out to secure this uniformity of action. Oil-pressure regulators similar to those used as regulators on steam mains have been tried, but in general have been found to be unsatisfactory, owing to the fact that the moving parts become clogged with sand or hydrocarbon; consequently the board has found that no so-called oil-pressure regulator used as a single device is satisfactory. A reliable plan is to provide the oil chamber of the pump with what would correspond to an air chamber on the water pump, or to provide a separate tank or chamber in which a constant air pressure is maintained on top of the oil by additional means. There are a number of designs of apparatus on the market which contain this feature of an oil air chamber, and corresponding regulating apparatus, which have given satisfaction. Many of these installations contain automatic arrangements whereby the change of level of the oil in the chamber effects a control of the steam supply to the oil pump, and thus affords an automatic method of controlling the quantity of the oil supply to the burner system.

In all oil installations it is very important that the control of the oil pump and of the steam to the burner or of the compressed air, where air is used, should be so arranged that in case the delivery of any one of these fluids is reduced, or interrupted, a corresponding reduction or shutting off should be effected in the supply of the other elements.

It is especially important that oil should in no case continue to be forced or pumped to the burners when the steam or air required for spraying is shut off, as in such an event the unsprayed oil is liable to flood in upon the hot brickwork and a furnace explosion is sooner or later likely to occur. The underwriters' regulations in many cases specifically require that in the event of the stoppage of the oil flow to the burner all the other functions shall be caused automatically to cease. These are precautions dictated by considerations of ordinary safety, and various applications of valves and devices are in the market whereby these results can be attained.

OIL-CARGO PUMPS.

For vessels carrying oil in bulk or for carrying oil in large quantities in their own bunkers it will be found desirable to install a special pump for the rapid pumping of oil either into or out of the cargo holds or ships' bunkers. Most oils, being sluggish in their motions, can not be readily handled by the pumps ordinarily used for the burners, and pumps of larger capacity are therefore required.

These cargo pumps will also be called into service while the vessel is at sea, for pumping the oil from one bunker or hold to another, in order to change the trim of the ship or to keep certain tanks at a desired level.

TANK VENTILATION.

In the storage of fuel oil on shipboard, it is of the highest importance, not only that the most careful attention should be devoted to the method and quality of rivetting, to secure oil tightness of bunkers and double bottoms, but that great care should be exercised in the design of the oil tank ventilation devices. It is well known that all crude oil generates more or less vapor of an explosive nature, and this vapor being heavier than the air rests upon the top of the oil in tanks or bunkers. This vapor can be removed by natural or artificial means, but as the formation of the vapor from a tank of oil proceeds rather slowly, it is usually found that a system of natural ventilation can be devised so that sufficient of the vapor can be easily removed.

All ventilating heads or cowls should proceed as direct as possible to weather decks, but should be located not too near the smoke stack. In all circumstances the oil ventilating cowls should be fitted with fine wire gauze soldered into the cowl opening. This wire gauze permits easy exit of vapor, while preventing any back flash into the vapor pipe from a stray spark from the main funnel or a light from a careless smoker on deck.

These oil ventilation cowls from their very exposed position are often caught by the rush of heavy shipped seas, and salt water is likely to pour down into them. Hence it is desirable to goose-neck these cowl pipes as is often done on board torpedo boat ventilator pipes, or to design a cowl pipe with a light ball float which will close under the presence of water in the manner of a check valve.

AIR COMPRESSORS.

In marine work it is generally recognized that compressed air should be used as a spraying medium rather than steam, in order to prevent the loss of fresh water which is entailed by the use of steam as a spraying medium. In the types of burners generally used the amount of compressed air required is considerable, and the sizes of air compressors installed are such as to constitute quite an addition to the mechanical apparatus placed in the engine room.

By reference to the columns giving the quantity of cubic feet of air used for boilers in the tests, as conducted by the experimental board, it will be observed that the cubic feet of free air required to effect vaporization for a given horsepower or fuel consumption is such that the size of the air compressor demanded is considerable.

The result of these considerations are that for marine purposes when vessels are intended for short voyages it will probably be found more satisfactory to buy water at the ports of call rather than to use the large and cumbersome air compressors required.

In very small marine installations, such as on tugs, air compressors of the Westinghouse air-brake type have often been used, but their proportional power consumption of steam is so excessive that their use is in no case to be recommended except where first cost or only occasional service is a ruling element.

Certain classes of burners have been operated with air at much lower pressures by use of blowers rather than air compressors. For marine purposes the results are somewhat more satisfactory, probably, than with the compressors, but still the blowers occupy considerable room in the engine or boiler rooms, and, as seen from the results of tests made by the board, there is somewhat of a question whether as satisfactory a combustion can be obtained with burners under low-pressure as with burners operating under high-pressure air.

When using air either at high or low pressure as a spraying medium it is exceedingly desirable that the air be superheated before passing to the spraying tip, as thereby a considerable gain in efficiency can be anticipated.

FURNACE CONSTRUCTION.

Where there is no desire to force the combustion of liquid fuel, the simple cylindrical furnace of the Scotch boiler has been found fairly suitable, particularly if an extension to the front of the furnace is made, so that complete combustion can be effected before the gases pass through the tubes.

With the water-tube boiler the problem becomes a more complicated one, at least so far as economy is concerned. Where the gases pass through the tubes, as in the case of the Scotch boiler, the resulting friction is sufficiently great to cause the gases to be abstracted of sufficient heat to produce a comparatively low temperature at the base of the stack. Where the gases pass around the tubes, as in the case of a water-tube boiler, there is but little impeding of the flow, and as a result stack temperatures are comparatively high. When burning oil in bent-tube types of boilers combustion is often only completed near the top rather than near the base of the stack or funnel.

The question of baffling of the gases in a water-tube boiler is one of supreme importance, for not only does it concern the economic efficiency but the endurance of the boiler itself. The straight-tube water-tube boiler ought, however, to possess special advantage for the burning of oil by reason of the fact that it is possible to secure a combustion chamber of considerable volume, so that complete combustion of the fuel can be effected.

Valuable information in relation to the naval boiler problem could have been obtained if the experiments had been continued sufficiently long to have experimented with different arrangements of baffling. There is but little doubt that it would have been found that the calorimeter opening should be decreased in a water-tube boiler where either coal or crude petroleum is used as a fuel. It will be observed that in some of the experiments where forced draft was used the reduced calorimeter opening proved very effective. Throughout the experiments it was apparent that in many respects the baffling of gases in modern water-tube boilers has been done without definite system, and that the relative efficiency and endurance of the various types can only be determined by the installation of a more efficient system of baffling.

It must be manifest that the question of water circulation is greatly dependent upon the problem of baffling, for unless there is a comparatively uniform heating of the tubes spasmodic circulation in water-tube boilers of every design is likely to occur.

The remarkable freedom from bending of the lower row of tubes of the experimental boiler was undoubtedly due to the presence of the horizontal baffle plates placed between the tubes for two-thirds of their length. As this baffling reached an incandescent state there was radiation from it to the lower row of tubes when the furnace doors were opened, and thus the tubes themselves were uniformly receiving heat either from the gases or from the intervening baffling. The fact that the lower row of tubes in the Hohenstein boiler were practically immune from a tendency to bend could only be ascribed to the nature of the baffling and the excellent character of construction.

Numerous experts had suggested to the board the necessity of giving special consideration to the question of arch construction so that there could be an impeding of the flow of the gases, in order that combustion could be completely effected within the furnace or amidst the tubes.

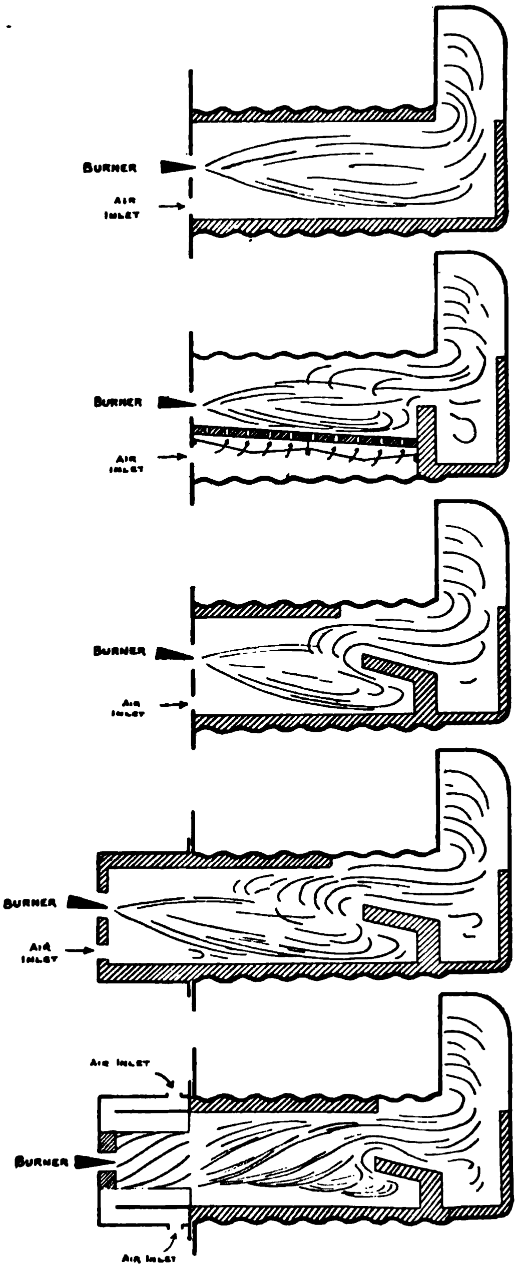
The accompanying sketches will show the various forms of brickwork that were used in the experimental water tube and the auxiliary Scotch boiler. The more experience the board had with arch construction the more convinced the members became that by reason of such construction being subjected to very severe heat and occasional chilling practically but little endurance could be expected. Before settling, therefore, upon any approved form of baffling arch the effort should be made to dispense entirely with any brickwork except a lining for a portion of the furnace length and a simple vertical bridge wall whose height could be increased or diminished at comparative trifling time, trouble, and expense.

FURNACE FORMS FOR SCOTCH MARINE BOILERS.

Scotch marine boilers, on account of their contracted volume of furnace, produce difficulties in the introduction of oil, and by reason of the small cubical space permissible for combustion purposes it is requisite that careful study should be given to the disposition of the brickwork in, or surrounding a furnace. It is, of course, quite possible to spray the oil at once into the metallic fire box or furnace of the Scotch boiler, the flame impinging on the cold surfaces of the steel plates; but although this is often done, yet it can not in any case be recommended as good practice. For successful combustion of oil it is requisite that the issuing oil spray should not too early in its progress of combustion strike the chilled or comparatively cold surfaces of the metal work. Carefully designed oil-burning furnaces require that the furnaces should be either partially or wholly bricked around.

As has been elsewhere shown in this report, the fact of heated brickwork is in itself a very great advantage in aiding combustion, and of still greater use in insuring perfect continuity of the heat supply, especially when burners tend to act in gusts, as they often do under improper action of the pumps, or where there is dirt or water in the oil supply.

The brickwork surrounding the interior of the Scotch furnace ought not to constitute a serious loss in thermal effect, because the brick itself early becomes incandescent and transmits a large portion of its heat directly to the metal in a steady and continuous flow.



I Burner spraying directly into the round bricked furnace. Often the bricking is omitted altogether, a practice not conducive to economy.

II Burner spraying directly over paved grate, set with fire brick with air openings. By raking out the brick this furnace is at once available for coal.

III Burner spraying into bricked furnace fitted with fire-brick wagon-top arch and separate combustion chamber.

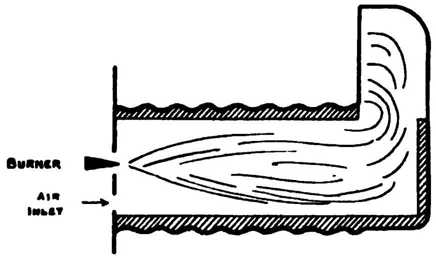
IV Extended fire-box furnace, giving longer sweep to oil flame. The wagon-top arch and combustion chamber are provided.

V Extended fire box with special spiralized air-heating device intended for use with mechanical burners or burners for high efficiency.

FIG. 98.—Oil-burning furnace forms for Scotch boilers.

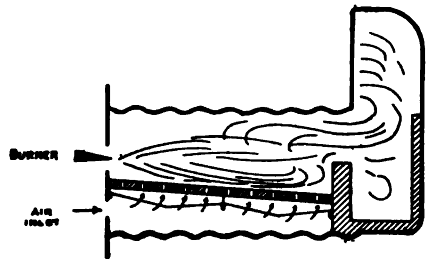
In the accompanying forms of furnaces shown the board has in all cases used or recommended for use, only simple forms of brick construction. Fig. 98 indicates in diagram the varied methods for burning oil in Scotch furnaces.

Furnace I indicates a corrugated furnace entirely surrounded with brick, and also bricked well up into the combustion chamber. The object of bricking into the combustion chamber, as shown, is for the purpose of protecting the back connection from the direct impact of the flames. The burner is installed in the middle of the fire door or furnace front, spraying directly into the round bricked furnace. This, it might be stated, is the general practice of firing oil into Scotch furnaces, the whole volume of the furnace being utilized in which the combustion can take place.



I Burner spraying directly into the round bricked furnace. Often the bricking is omitted altogether, a practice not conducive to economy.

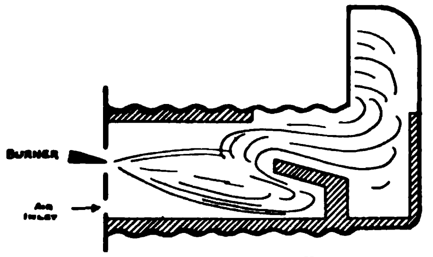
Fig. 99.



II Burner spraying directly over paved grate, set with fire brick with air openings. By raking out the brick this furnace is at once available for coal.

Fig. 100.

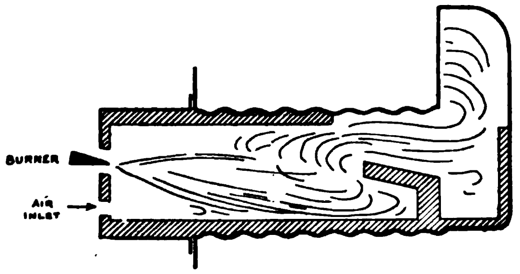
Furnace II represents the combustion chamber still bricked, with the usual bridge wall left in place and the standard form of grate bars left intact; but on top of the grate bars is formed a paving of fire brick with interstices left between the bricks, or the bricks may be placed checker-wise. The bearing and grate bars with the ash pit necessarily take up so much of the cubical space of the furnace that it would be inexpedient to brick up the entire interior surface of the furnace, as in the former case, as there would not be left cubical volume sufficient to insure proper combustion. In the combustion of oil fuel it is recognized that as much volume should be allowed as the formation of the furnace permits. The burner is installed in the regular fire door and sprays directly over the paved grate, the requisite air for combustion coming through the openings in the grate, and perhaps also a certain amount along the burner opening. The advantage of the furnace setting on this plan is that the oil-burning installation can be removed at very short notice, the paving of fire bricks on the grates can be easily raked out, and in the short space of an hour or more the furnace can be firing under the use of coal. Many steamship managers prefer to equip their furnaces in this way, as they therefore feel that they are then in a position to make use of either fuel as the conditions of the market or the supply of fuel in the ports where their steamers visit will warrant.



III Burner spraying into bricked furnace fitted with fire-brick wagon-top arch and separate combustion chamber.

FIG. 101.

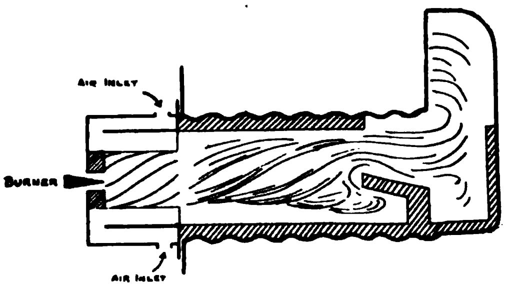
Furnace III represents the Scotch furnace equipped with a small wagon-top arch, and behind the arch, space is left for a combustion chamber. The main part of the furnace is bricked over for the reasons as heretofore indicated, the portion not bricked being directly over the arch, for the purpose of not too seriously checking the flow of gases passing over the arch. The burner installed in the furnace mouth sprays rather downward and into the arch, the flame reverses on itself, flows over the arch into the combustion chamber and to the tubes. This furnace has the advantage of insuring an intimate mixture of the flames of combustion and gases, but has the disadvantage of shortening up the total length of the active part of the furnace.



IV Extended fire-box furnace, giving longer sweep to oil flame. The wagon-top arch and combustion chamber are provided.

FIG. 102.

Furnace IV indicates a style of furnace setting similar to the previous example, except that the furnace is extended outward by a projecting casting, thus increasing the total available length of the furnace. This casing is filled with fire brick, and being over a portion of the oil flame, which is itself not very hot, the casing therefore does not radiate any disagreeable heat to the fireroom. This form of setting has the desired feature of affording a longer scope to the play of the oil flames, and consequently the gases are not so likely to pass to the tubes before complete combustion is attained. With the forms of burners designated as straight-shot burners it is important that this length of extended furnace should be used in order to obtain the full advantage of the oil. The experiments of the Board have indicated that when the burners are located too near the bridge wall that a deposit of soot, coke, or carbon forms on the bridge wall, and in time is likely to give trouble by choking up air passages or seriously decreasing the volume in the furnace.



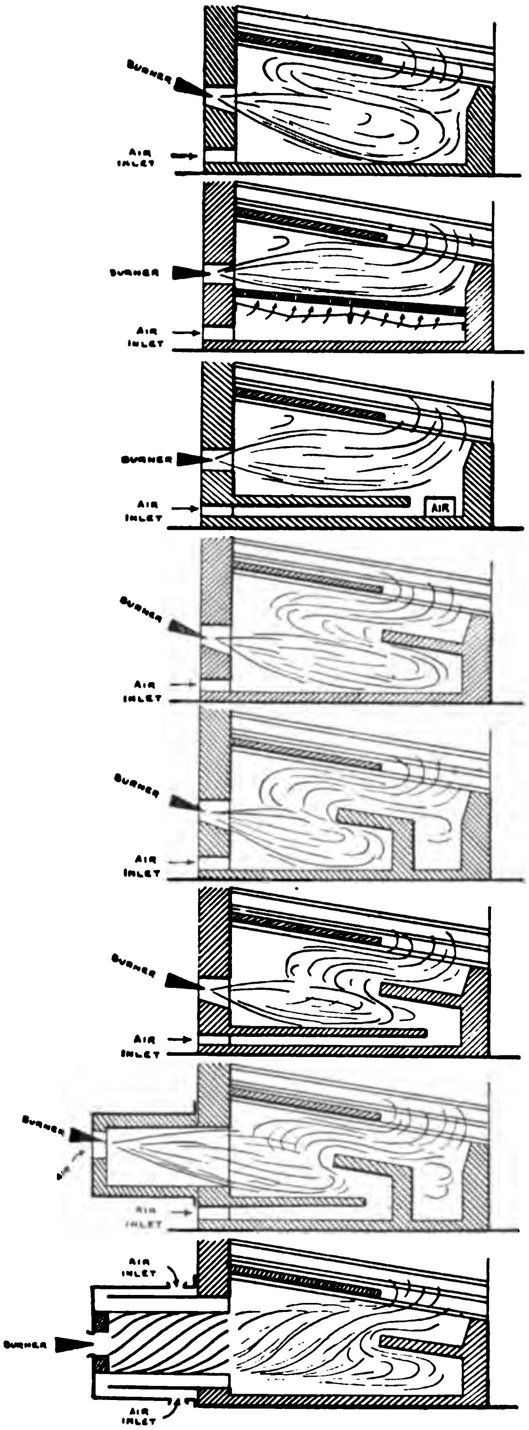
V Extended fire box with special spiralized air-heating device intended for use with mechanical burners or burners for high efficiency.

FIG. 103.

Furnace V is representative of a type of furnace so far made use of only where mechanical forms of burners are used—that is, burners operating without the use of compressed air or steam. When using these mechanical burners, as elsewhere shown in this report, it is a desideratum that the air for combustion should be brought to the burners with as great a temperature as possible, and also, when conditions permit, it is desirable to give the air currents a certain amount of rotation. These hot twirling motions of the air are an important element in securing the desired efficiency of the combustion. The bridge wall or the wagon-top arch may or may not be used, but in all classes of furnace it is desirable if possible to introduce them, provided a proper fire brick can be obtained which will stand the tremendous heat generated by oil-flame formation.

OIL-BURNING FURNACE FORMS FOR WATER-TUBE BOILERS.

Water-tube boilers have usually somewhat greater volume in their fire boxes than the furnaces of the Scotch boilers, consequently the opportunities are greater to arrange the brickwork to suit the peculiar conditions required by oil fuel. With most of these boilers it is quite customary to put the burners into the fire doors or the spaces which would have been occupied by fire doors. As a matter of fact, it would often be better to put the burner at the back of the boiler and fire toward the front of the furnace, as by this means the larger end of the furnace would receive the gases of combustion at the point where the greatest expansion was taking place.



I Burners spraying into square open furnace, from which grate bars have been removed.

II Burners spraying directly over a paved grate, set with fire brick with openings for air. By raking out the brick this furnace is at once available for coal.

III Burners spraying into a furnace fitted for a hot-air floor. Also when necessary, a side opening for air.

IV Burners spraying into a furnace fitted with flat arch or a series of wagon-top arches.

V Furnace fitted with flat or wagon-top arches, with a combustion chamber behind the arch.

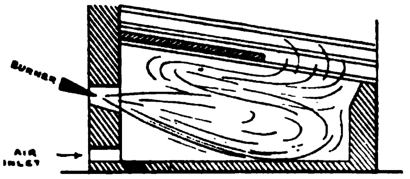
VI Furnace with hot-air floor and arches.

VII Extension furnace for affording longer sweep to flame. The hot-air floor and arches also provided.

VIII Extension furnace with special spiralized air-heating device, intended for use with mechanical burners or burners for high efficiency.

FIG. 104.—Oil-burning furnace forms for water-tube boilers.

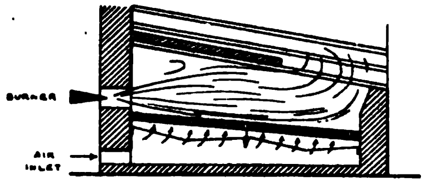
Owing to the fact that all the gauges, fittings, and connections are on the front of the boiler, it becomes an advantage to have the burner also, therefore, located on the front rather than on the back, where it would be practically inaccessible. In all the tests of the Board and in the proposed furnace modifications submitted the burners have been installed in the front of the furnace, as shown.



I Burners spraying into square open furnace from which grate bars have been removed.

FIG. 105.

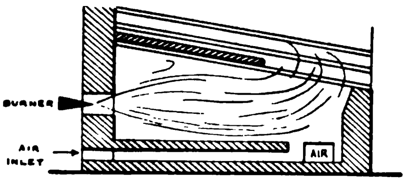
Furnace I (fig. 105) indicates the burners spraying into the square open furnace of any of the standard water-tube boilers. The grate bars have been removed and the entire volume of the furnace is available in which to effect combustion.



II Burners spraying directly over a paved grate, set with fire brick with openings for air. By raking out the brick this furnace is at once available for coal.

FIG. 106.

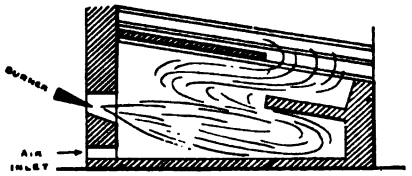
Furnace II shows a modification in which the regular grate bars have been left in place, and the grate bars have been covered with a paving of fire brick, arranged with proper spacing between bricks for the admission of air. The burners are adjusted to fire directly over the paved brick on the grates. This furnace has the advantage that at any time it is possible to rake out the fire brick and at once to return to the use of coal as a fuel. The disadvantage is, however, that the cubical contents of the furnace have been very seriously reduced by retaining the grates and the paving in place.



III Burners spraying into a furnace fitted for a hot-air floor. Also when necessary, a side opening for air.

FIG. 107.

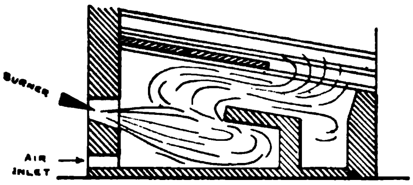
Furnace III shows the bottom of the furnace constructed of a thin layer of brickwork, so arranged that the impinging of the hot gases and the effects of radiation cause the floor to be heated to a considerable temperature. The entering air for combustion passing under this floor becomes quickly heated, and adds quite an element to the efficiency of the oil-burning operations. As shown in the detailed plans in this report, many of the tests of the Board were conducted with this style of flooring, and the results were usually found to be satisfactory for the purpose intended.



IV Burners spraying into a furnace fitted with flat arch or a series of wagon-top arches.

FIG. 108.

Furnace IV shows the introduction into the furnace of a flat arch or a series of wagon-top arches. The burner is arranged to point rather downward, so that the oil flame is directed under the arch, the current of the hot gases then reverse upon themselves, flow over the arch, and to the tubes. The introduction of the arch makes a desirable arrangement where the shape of furnace permits and where a satisfactory quality of fire brick can be obtained which will stand this rush of heat under and over it. Cored arches for this purpose have been designed in which a current of air is brought through the body of the arch, thus keeping down the temperature of the arch blocks themselves, and at the same time imparting a considerable degree of temperature to the incoming air.

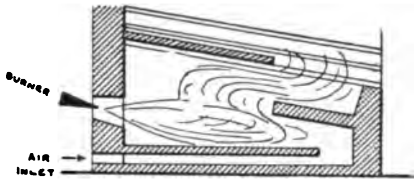


V Furnace fitted with flat or wagon top arch with a combustion chamber behind the arch.

FIG. 109.

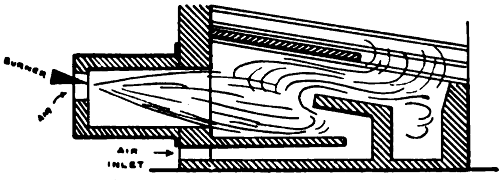
Furnace V is essentially the same as in the previous class, except that behind the arch a small combustion chamber has been devised to permit of a further expansion of the hot gases and more intimate mixture after passing over the arch and before entering the tubes. Constructed in this manner the furnace is liable to give trouble, due to the fact that the burner then is located too near the arch, and carbon will be deposited on or under the arch unless a burner of a short-spraying type is adopted.

Furnace VI is the same as the furnace represented in IV with the addition of the hot-air floor shown in furnace V. This combination of the arch and the hot-air floor produce a very efficient furnace arrangement, and one calculated to give good results.



VI Furnace with hot-air floor and arches.

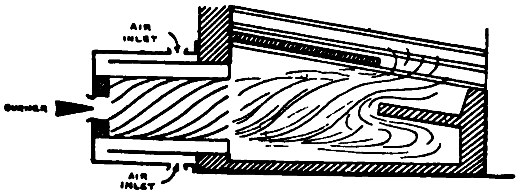
FIG. 110.



VII Extension furnace for affording longer sweep to flame. The hot-air floor and arches also provided.

FIG. 111.

Furnace VII shows an extension furnace for affording additional sweep to the flames. This extension is bricked with fire brick so as not to radiate heat into the fireroom, and to incidentally impart some heat to the flame by radiation. The wagon-top arch, or flat arch, and the hot floor are also introduced for the advantages which each confer.



VII Extension furnace with special spiralized air-heating device, intended for use with mechanical burners or burners for high efficiency.

FIG. 112.

Furnace VIII shows an extension furnace, with special spiralized air-heating device, designed for use with mechanical burners or other burners where it is desirable that the flames should be fed by a hot-air current. The arch formation can be used or not, as desired.

VARIOUS TYPES OF FURNACES.

The board did not consider it advisable to undertake the experimentation with boilers of the usual forms, specially known as land types, such as outside-fired shell boilers, particularly as a large number of accurate experiments have been conducted by others to determine the results and efficiency of oil consumption under such types of boilers.

The prevailing opinion appears to be that the details of the arrangement of furnace for oil burning are more easily designed and installed for use under stationary boilers than in the marine type, owing to the fact that more room can be had for the necessary combustion space in the large and wide fire boxes in which proper distribution of fire brick for the heated gases can be obtained.

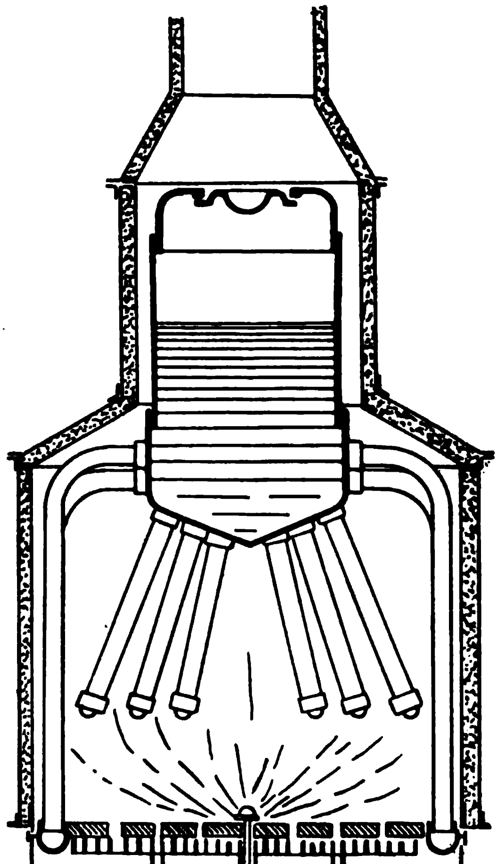


FIG. 113.—Application of oil burner to the Navy type of launch boiler of Ward form

There was, however, brought to the attention of the board the possibilities of the use of oil in small vertical boilers, such as the types largely used on the standard launches of the United States Navy, or boilers of the small-tube type, which are now usually installed in torpedo boats and torpedo-boat destroyers. These boilers and their fire boxes are of numerous types, with the result that the fire-box conditions likewise have great variation.

In fig. 113 is shown a cross section through the vertical water-tube type of boiler used in the standard navy launch. As proposed for the use of oil, the burner would be located in the center of the grate, the grate bars being covered with fire brick so placed as to allow numerous small openings to provide the requisite draft for combustion. The firing door proper would be bricked up, allowance being made for a sight-hole from which to view the operation of the flame.

CONFIRMATORY EVIDENCE AS TO RELIABILITY OF THE DATA SECURED BY THE LIQUID FUEL BOARD.

Previous to the conduct of these tests various engineering experts had made reports showing that during experimental trials there had been evaporated from and at 212° as high as 17 pounds of water per pound of oil fuel. When the preliminary report of the board was issued, showing that no expert had been able under commercial conditions to secure with an ordinary marine boiler an evaporation of 15 pounds of water per pound of oil combustible, where there was no heating of the air requisite for combustion, as in the Howden system, it was asserted in some quarters that there had been lack of knowledge or skill in the operation of the burners.

The board has received from one of the leading oil centers of this country the following data in regard to a comparative test of leading forms of oil burners used for manufacturing and marine purposes.

Among other conclusions formed by the Liquid Fuel Board was the opinion that neither evaporative efficiency nor capacity was primarily dependent upon the design of oil burner, but that the character of the installation was all-important. This conclusion has been supported by these official tests since the burner designated "R," which was made of gas-pipe fittings, was one of the most efficient where there was not severe forcing of the boilers. It should be stated that each of the burners, whose commercial names are represented by the letters "A" to "Q," inclusive, is a well-known patented appliance and a burner that finds a ready sale in special localities.

It should be further stated that the seventeen distinct forms of burners used during these experiments were installed and operated by experts. While some of the tests were of very short duration, sufficient information was secured to show that it will be the rare exception in actual practice where the evaporative results secured by the Liquid Fuel Board will be exceeded in actual commercial or maritime practice. Where the air requisite for combustion is heated, as in the Howden system, and where properly designed retarders are fitted in a Scotch boiler, and with an extension to the front of the furnace, the evaporative efficiency will be increased. It will be noted that the oil pressure as well as the pressure of the spraying medium was different for the several burners. The several appliances were operated under the special conditions for which they were designed to be used, and thus the highest possible efficiency was secured from them. There is not the slightest doubt but that the difference in results secured from operation of the several forms of burners would have varied even more if the installation of auxiliaries and piping of the different devices had been left to other than experts.

The data of these tests should be studied in connection with the summary of the extended series of liquid-fuel tests conducted by the naval board.

Designation of burner.	Duration of test.	Revolutions per minute of air compressor.	Water evaporated per hour from 100° F.	Oil burned per hour.	Water per pound of oil from and at 100° F.	Water per pound of oil from and at 212° F.	Free air per burner per minute.	Free air per pound of water from and at 212° F.
	Hours.		*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Cubic ft.*	*Cubic ft.*
A..........	3	69.4	4,851.5	488	9.94	11.48	54.5	1.17
B..........	6	55.2	7,068	701.5	10.08	11.63	43.34	.6375
C..........	4½	41.8	4,761.9	461.4	10.32	11.92	32.8	.7159
D..........	2	60.3	4,971.6	472	10.53	12.15	47.4	.99
E..........	6	58	5,080.9	477.5	10.64	12.24	45.25	.926
F..........	3	56.6	4,675.8	430	10.87	12.54	44.5	.99
G..........	6	56	5,927.46	542.3	10.93	12.63	44	.89
H..........	6	61.2	5,706.6	520.7	10.96	12.66	48.1	.875
I..........	3	38.6	4,010.6	364	11.03	12.7	30.4	.787
J..........	6	68	5,172.48	459.7	11.25	12.99	53.42	1.072
K..........	6	42	4,658.4	411.5	11.32	13.07	33	.846
L..........	1½	40.9	5,158.9	455	11.34	13.08	32.1	.65
M..........	54⅔	60.7	5,379	470.4	11.43	13.19	47.65	.921
N..........	6	49	5,310.4	460.7	11.53	13.30	39	.87
O..........	6	62.75	5,430	471	11.54	13.33	49.3	.943
P..........	6	58.2	6,369	532	11.98	13.82	45.75	.748
Q..........	3	45.4	5,376	444	12.099	13.96	35.6	.69

Designation of burner.	Free air per pound of oil burned.	Average temperature of feed water.	Average temperature of smoke-pipe gases.	Average steam pressure at boiler gauge.	Average pressure of air for atomizing.	Horse-power of boiler.[a]	Average oil pressure.	Free air per pound of water evaporated from and at 100° F.
	Cubic ft.	° *F.*	° *F.*	*Pounds.*	*Pounds.*		*Pounds.*	*Cubic ft.*
A..........	13.4	99.56	837.5	94	20	162.4	20.6	1.348
B..........	7.41	102	1,040	93	20	236	30.8	.736
C..........	8.54	100.9	698	94	20	159.4	14	.827
D..........	12.05	99	784	90	20	166	19	1.144
E..........	11.38	101.5	792	92.3	20	170	18	1.069
F..........	12.4	101	702	90	20	156	20	1.141
G..........	9.74	102	800	94	17	198.4	10.3	.891
H..........	11.08	101	858	94	20	191	29.1	1.011
I..........	10	100	([b])	82.3	20	134	20	.907
J..........	13.9	100.5	775	94.6	20	173.17	10.3	1.239
K..........	9.62	100.5	973	93.5	28.5	156	20	.859
L..........	8.48	101	([b])	([b])	20	172.6	19.4	.747
M..........	12.16	100	([b])	92	60	155.91	50	1.06
N..........	10.02	101.5	621	93	20	178	21	.869
O..........	12.56	100.3	660	95	20	182	20.2	1.09
P..........	10.32	101	709	89.3	20	213	29.5	.863
Q..........	9.6	100.5	686	89	20	180	21.8	.790

[a] Unit equals 30 pounds water at 100° F. into steam at 70 pounds gauge pressure. [b] Not taken.

Above tests made with air atomizers. Heating surface of boiler, 1,180 square feet; grate surface of boiler, 27.5 square feet; 2 furnaces, 30 inches diameter, 6 feet long; 9 Galloway tubes; 113 3-inch tubes.

Conditions imposed: Gravity of oil, 16 to 23 Baumé; steam pressure allowed for atomizing, 80 pounds per square inch of gauge; pressure of oil allowed at burners, 10 pounds to 40 pounds per square inch; steam pressure in boiler, 90 pounds per square inch; water to be evaporated per hour, 5,000 pounds.

NECESSITY OF PERMITTING UNOFFICIAL OR PRELIMINARY TRIALS.

Between the several official tests conducted by the Naval Fuel Oil Board there were invariably undertaken a number of unofficial trials, and by reason of this preliminary experimentation, important information was obtained and many improvements suggested by modifying the various installations. Those receiving permission to install their appliances, invariably found it quite a different matter to operate burners when fitted to a boiler capable of developing 2,000 horsepower, from what it was to install the device on a steam generator that supplied the motive power to the machinery of either a small vessel or medium-sized manufacturing plant.

With one or two exceptions, no firm has been able, without conducting preliminary tests, to tell the board the best manner in which under forced-draft conditions their devices should be operated. In fact the details of installation of every burner officially tested was quite different from that projected at the beginning of the test. The two or three days that were given to experimental trials invariably furnished surprises to the inventor. Probably no better illustration could be given of the lack of definite knowledge in regard to the correct way of operating burners than was shown during these tests by the inventors of oil burners in the management of such appliances.

The experience of the board in this particular respect, shows the necessity, for naval needs, of having disinterested experts conduct extended series of tests to determine the guiding principles, which should be followed in fitting different types of naval vessels for burning liquid fuel. There has been sufficient evidence already secured to prove that in all probability a special design of installation will be required for different types of boilers. It can hardly be expected that an installation which could do efficient and economical work in some small land boiler, will always be equally applicable to a large steam generator of the marine type.

In noting the evaporative efficiency secured it should be remembered that the experimental boiler was designed for actual Navy conditions, and that the limitations prescribed by the Department as to height, weight, and floor space were of a severe nature. There was not only considerable radiation from the boiler, but the proportion of heating to grate surface was not as large as in land boilers, due to limitations imposed by the Navy Department. Taking these facts into consideration, the efficiency results are exceedingly satisfactory. The capacity tests have never been surpassed. The engineering world looked for comparative results from the series of tests that were conducted, and trustworthy information in this respect has been secured and furnished.

SOURCES OF THE OIL SUPPLY USED FOR EXPERIMENTAL PURPOSES.

From various sources the Bureau received offers to supply free of cost at the wells all the oil required for experimental purposes. After careful investigation it was found that if such offers should be accepted, great difficulty would doubtless be experienced in securing shipment of the product to the experimental plant. As the facilities for the transportation of oil are practically controlled by a few corporate interests, the board soon discovered that in order to provide for an adequate and reliable supply of such fuel it would be essential to deal only with those who could guarantee the timely shipment of the oil requisite for experimental needs.

It was fortunate that such action was taken, for by reason of the limited number of oil-tank cars in use, continued trouble was experienced in securing a sufficient supply of oil requisite for conducting the tests.

No attempt was made to determine the evaporative efficiency of either the Pennsylvania or the Ohio crude petroleum product, since practically the bulk of the supply of these districts, pumped through the pipe line to the Atlantic coast, is used for illuminating purposes. For marine work, at least, the cost of such oil delivered at the seaboard is a bar to its use as a combustible.

The tests were, therefore, made with the Texas and California products, for the reason that the output of these fields is not being entirely absorbed for illuminating and commercial reduction. The Texas oil was procured from the Standard Oil Company. The board is under special obligation to the officials of that corporation for assistance in keeping the experimental plant supplied with fuel. There were times when the supply of Texas oil reaching the North Atlantic ports was so limited that the orders of regular customers could only be supplied in part. The oil required for operating the naval experimenting plant was often secured only through persistent appeals and by the active help of individuals connected with the service of this company.

It required months of persistent effort to secure several car loads of the California product for experimental purposes, although the Engineer in Chief of the Navy, Rear-Admiral Melville, made urgent appeals to the presidents of various transcontinental railroads to furnish cars for the transportation of this oil. In order to expedite delivery there was no limit placed on the cost of such shipment.

It was finally through the personal effort of Dr. C. T. Deane, secretary of the California Petroleum Miners' Association, and Col. W. M. Bunker, the Washington representative of the San Francisco Chamber of Commerce, that three shipments of oil were secured. The board takes this occasion to bear testimony to the extent and value of the information furnished by these gentlemen in regard to the development of the use of liquid fuel on the Pacific coast. The personal work done by these officials in acquainting the board with the possibilities of the oil development of California is deserving of the most substantial recognition by all having an interest in the subject, and particularly by all connected with the development of the oil industry on the Pacific coast. The board has no hesitancy in stating that if it had not been for the reliable, continuous, and valuable supply of information that had been furnished the board during the past two years by these representative officials, the industrial, maritime, and military importance of the California product to national interests could not have been appreciated in its fullness by the Liquid Fuel Board.

There were cogent reasons why both the California and Texas products should be used under the same experimental boiler, and probably the only reliable comparative experiments ever conducted as to the value of the two products were those made during these tests.

From a naval standpoint it may be much more important to further investigate the possibility of using the California rather than the Texas product. Coal is quite scarce and expensive on the Pacific coast, as compared with the output and cost on the Atlantic coast, while the reverse is the case as to the cost of oil. It will be on the Pacific coast, therefore, that oil will find its most important use for naval purposes, and on this account the data in regard to the California product should be of substantial value.

Probably no more impressive way could be shown of telling how unreliable is the source of supply of liquid fuel on the North Atlantic coast, than by stating that it was probably the personal appeals of individuals, rather than the demands of the experimental plant, which insured the regular delivery of the comparatively limited quantity requisite for test purposes. The present lack of supply of the Texas product at the northern Atlantic ports, is possibly due to the fact that there are too few tank steamers in operation, and that the failure of a half dozen of such vessels at any time to make regular trips, always seriously embarrasses a large number of special interests whose industrial demands compel them to use oil as a fuel.

THE RELATIVE VALUE OF COAL AND OIL AS A FUEL.

Probably no more striking way of actually showing the relative commercial value of coal and oil as a fuel, could be presented than by stating that the Atchison, Topeka and Santa Fé Railroad Company made the following comparative tests, of the cost per train mile, of coal costing $6.65 per ton and petroleum costing $1.33 per barrel:

Twenty-five passenger and freight engines on a thirty-day run, used 2,077 tons of oil and traveled 87,063 miles, or 41.9 miles per ton, or 3,500 miles per month per engine. Oil at $1.33 per barrel would, at this figure, cost 14.4 cents per mile. Twenty-five passenger and freight engines (same days, same track, and same condition) burning coal, cost 23.2 cents per mile. The oil was 15° Baumé, about the same as the Kern River oil, which is 14° to 17° Baumé; this showed a saving for oil of 38 per cent, and the experiment was tried with coal at $6.65 per ton.

In this extended and practical test the cost of the oil per barrel was one-fifth of the cost of the coal per ton, while the resulting gain for oil was 38 per cent. Stated in another form, the value of the two fuels would be the same when the price of the coal in tons was three and one-half times the price of the oil in barrels.

The appended chart showing the respective prices of crude oil at New York, San Francisco, and Point Sabine, as well as the prices at the Pennsylvania and California wells, will show the exceeding cheapness of the San Francisco product, and of the stability in price as compared with the Texas and particularly with the Pennsylvania yield. These prices, studied in connection with the oil productions of the various districts, ought to show the field for marine uses of crude petroleum that will eventually be found in the Gulf of Mexico and along the California coast.

The fact that the Atchison, Topeka and Santa Fe Railroad Company was compelled to pay $1.33 per barrel for fuel oil, although the road traversed an oil district, is striking evidence of the increase in cost over the price at the wells to the consumer by reason of the expense attendant upon light refining and transportation.

Prices of Texas petroleum delivered at Texas seaboard.

[Prices, in cents per barrel of 42 gallons. Maximum and minimum prices for each month.]

1902—January	8	to 15
February	15	25
March	15	30
April	17	25
May	20	25
June	20	25
July	15	20
August	20	25
September	25	35
October	30	45
November	35	40
December	40	55
1903—January	50	55
February	52	60
March	65	[a]85
April	75	[a]85

---

[a] Sales said to have been made at higher rates.

1903—May	70 to	80
June	73	80
July	35	60
August	25	35
September	35	50
October	30	50
November	32	45
December	45	70
1904—January	30	52
February	30	50
March	25	42

Prices of Pennsylvania oil in New York market and at wells.

Date.	Pennsylvania in New York market. Per gallon.	Pennsylvania in New York market. Per barrel.	Pennsylvania at wells (pipe-line certificates), per barrel.
1901.	*Cents.*		
April	5.50	$2.31	$1.30
May	4.70	1.97	1.11
June	4.35	1.83	1.04
July	4.35	1.83	1.04
August	4.95	2.09	1.25
September	4.95	2.09	1.25
October	5.10	2.14	1.30
November	5.10	2.14	1.30
December	5.10	2.14	1.30
1902.			
January	4.65	1.95	1.15
February	4.65	1.95	1.15
March	4.65	1.95	1.15
April	4.65	1.95	1.15
May	4.85	2.04	1.20
June	4.85	2.04	1.20
July	4.85	2.04	1.22
August	4.65	1.95	1.22
September	4.65	1.95	1.22
October	4.65	1.95	1.22
1902.	*Cents.*		
November	4.90	$2.06	$1.33
December	5.50	2.31	1.45
1903.			
January	5.75	2.42	1.54
February	5.65	2.37	1.50
March	5.65	2.37	1.50
April	5.65	2.37	1.50
May	5.45	2.29	1.50
June	5.65	2.37	1.50
July	5.65	2.37	1.53
August	5.65	2.37	1.56
September	5.65	2.37	1.56
October	5.95	2.50	1.62
November	6.40	2.69	1.77
December	6.40	2.69	1.87
1904.			
January	6.20	2.60	1.85
February	5.95	2.50	1.74
March	5.75	2.41	1.71

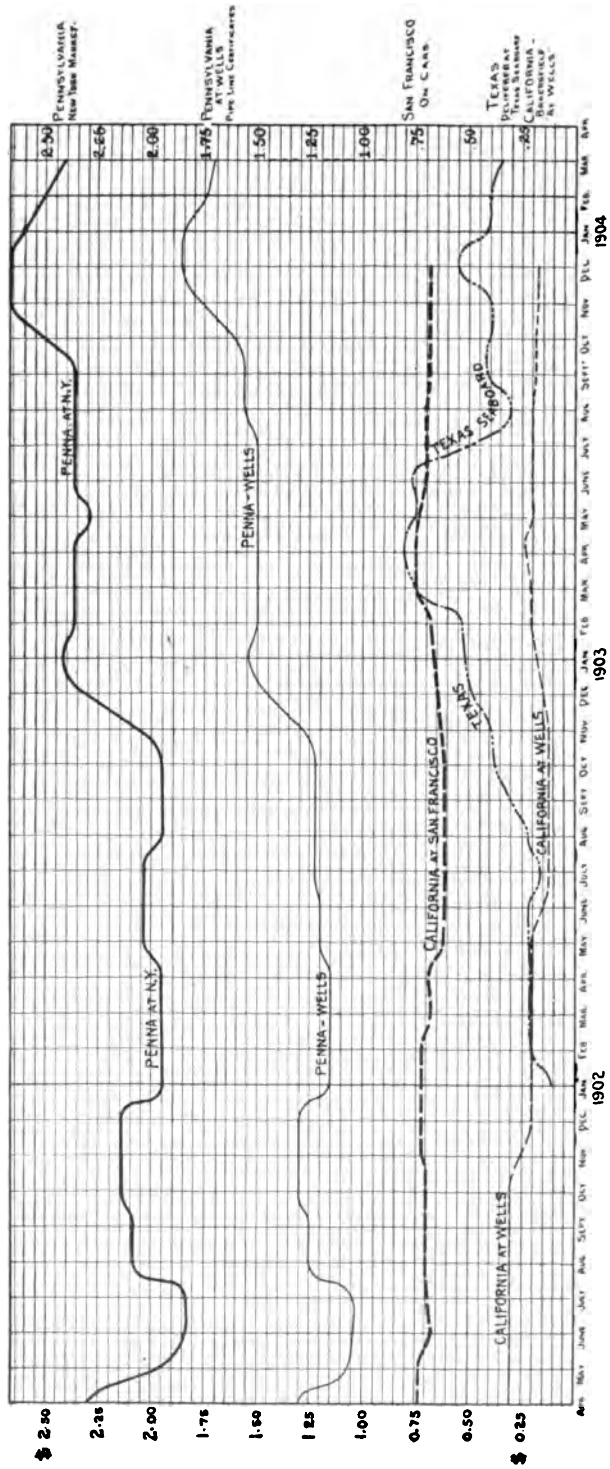


FIG. 114.—Crude oil prices, in barrels of 42 gallons each, in United States markets for three years

STRUCTURAL, TRANSPORTATION, AND SUPPLY FEATURES OF THE OIL-FUEL PROBLEM GREAT BARS TO THE USE OF SUCH FUEL ON BOARD FIGHTING SHIPS.

The mechanical or engineering feature of the oil fuel problem has been practically solved. The financial feature should not be regarded as of serious importance in the solution of any naval fuel problem, since it would be just as logical to fill the magazines of a war ship with an inferior quality of powder as to stow the bunkers with a poor steaming fuel. The question of cost as to fuel supply for naval purposes should not, therefore, receive undue consideration.

At the present time it is the structural, transportation, and supply features which present the only serious difficulty to the adoption of the use of liquid fuel by the navies of the world.

The transportation and supply features may be regarded as the commercial side of the problem. In regard to this phase of the question the Engineer in Chief of the Navy, in his annual report for 1902, thus comments:

> The commercial feature of the liquid-fuel problem relates to the question of cost and supply. It may be regarded as a certainty that, except wherein unusual conditions prevail, the cost of oil for marine purposes will generally be greater than that of coal. The cost of oil, however, is less for vessels departing from the Gulf and California seaports, but the rule will probably hold elsewhere. While the question of cost should be of secondary importance in military matters, it must be taken into consideration in industrial matters. It is the expense of transportation that now prevents the oil from being a cheap combustible for marine purposes, but this disadvantage ought to be soon removed. While the oil may be put in the tank steamer very cheaply at ports like Point Sabine, its commercial value will be determined by the cost of delivery at commercial and maritime centers. This feature of the problem is beyond the ability of the Navy to control, but it must be regarded as an important phase of the subject.
>
> In considering the matter of cost the fact should be remembered, however, that but comparatively few tank steamers are carrying oil between Point Sabine and the North Atlantic seaports. The expense of fitting up these vessels has been very heavy, due to the fact that unexpected difficulties developed in the cost of making the installations. This has compelled the owners of the oil steamers to charge comparatively high prices for transportation of the fuel. It can certainly be expected that when a large fleet of vessels are used for carrying oil and when terminal storage facilities are provided that there will be a material decrease in the price of oil in the leading cities on the coast. This is a very important commercial phase of the question, and should be carefully considered in determining the probable relative value of the two combustibles in the early future.
>
> It is undoubtedly a fact that the transportation charges per mile for oil at the present time are excessive compared with the freightage for coal, and this incongruity of expense account against oil can not continue much longer.

As regards the question of supply, it may be more expensive if not difficult to transport and to store oil than coal. The fumes of all petroleum compounds have great searching qualities, and therefore extreme precaution will have to be taken to guard the storage tanks. If it be true that for military purposes it is best in time of war to keep all reserve fuel afloat, then liquid fuel is at a disadvantage in this respect. The mining and railroad companies have invested so heavily in the coal industry and the transportation facilities have been so perfected that it is now possible to quickly deliver a cargo of coal at any point in the world. There has been, likewise, a development in the method of loading and unloading cargoes of coal. Since it will require progressive development to perfect the transportation and the storage of oil, and as the world's supply is still an unknown quantity, it will be some time before there may be a reserve supply of oil at the principal seaports.

It must also be remembered, when considering the problem of supply, that the naval vessel must be kept in readiness for orders to proceed at any time to any port within her steaming radius. The merchant vessel steams between regular seaports, where it would not be difficult to induce merchants to keep a supply of oil as soon as there is a regular and constant demand for it. The question of oil supply for battle ships and cruisers may therefore not only be a commercial affair, but prove to be a military problem, since the oil requirements of naval vessels for service conditions might only be met by the Government establishing oil-fuel stations. The military aspect of the establishment of fuel stations may prove to be a serious problem, since it may not only necessitate heavy expenditures, but may involve the greater political question as to the wisdom of maintaining a complete chain of fuel stations between country and colony.

The more carefully, however, the structural problem as regards a fuel installation on a battle ship is considered, the more difficult and complicated appears its solution. The storage of oil fuel on board the armored cruiser or battle ship, or what might be termed the structural feature of the problem, is thus undoubtedly the great deterrent to the use of what may popularly be regarded as an incomparable fuel for war-ship purposes.

In the war ship, the oil fuel will probably have to be carried below the protective deck; in fact, as far below the water line as possible. In the merchant service the tanks often rise to the height of the main deck. In the war ship, however, considerable space must be found in the lower portions of the vessel for the storage of ammunition and ship's equipment, thus rendering it exceedingly difficult to secure beneath the protective deck sufficient space for the storage of the oil supply.

Crude oil is a great searcher, and unusual care will have to be exercised in the construction of tanks or receptacles on board war ships for the stowing of such fuel. Some of the resulting gases from the volatilization of liquid fuel are not only poisonous but explosive, and being much heavier than air, their removal from the storage tanks will be a very difficult matter.

Not only will it be necessary to increase the number of fuel compartments if oil is substituted for coal, but greater care will have to be exercised in making the bulkheads tight. In order to increase the safety of such vessels it would be essential to have the various oil compartments absolutely distinct from each other.

In the loading and unloading of oil-carrying steamers, fires are always hauled from the galleys and boilers of the vessels. On board the war ship, where a large crew has to be housed, the putting out of the galley fires would subject the crew to much inconvenience. The modern war ship is now crowded with so many auxiliaries, that steam must be maintained in some of the boilers of naval vessels at all times, and therefore the dangers attendant upon the stowage of oil in war ships will be much greater than that in merchant vessels.

It is the belief of the board that if oil fuel is ever used on board war ships, it will be essential to make the containing walls of the oil tanks much heavier than in the case of the ordinary water-tight bulkhead. The formation of heavy gases that will accumulate as the amount of liquid fuel decreases will constitute a great danger. The more the tanks are depleted the greater will be the danger from a possible explosion. The general structural arrangement of the battle ship, even now is of such character that the satisfactory ventilation of every compartment has not been secured, and particularly will such be the case where the fuel supply is of oil rather than of coal.

In all probability the great bulk of the oil in the war ship would have to be kept in the double bottoms. As the petroleum vapors are quite heavy, it may be a difficult matter to free these compartments of explosive gases, especially when the compartments are partly empty. By reason of the great number of electrical appliances in use on board the war ship hundreds of sparks are likely to be caused, any one of which might cause an explosion and set the oil fuel on fire.

In submarine boats no effective way of rapidly removing the noxious and explosive hydrocarbon gases from the gasoline engines has yet been devised, although the hulls of such boats are simple spindles with a large opening or conning tower in the center. Experience with gasoline vapors in this class of naval construction will give some idea of overcoming the greater problem of removing gases from the numerous small compartments of a battle ship. The difficulty of freeing the compartments of the heavy and explosive gases is almost a problem within itself, and will require extended investigation and experiment before any naval power seriously considers the proposition of installing an oil-fuel system exclusively on board a war ship.

With oil as a fuel it will be essential to provide a very complex installation of piping. It may be necessary to make arrangements whereby live steam can be admitted to each compartment for the purpose of putting out fires and also for the removal of the heavy gases. The condensed water resulting from this steam will have to be removed to prevent corrosion of bulkheads. Experience may also show the necessity of having a system of piping whereby the oil compartments could be flooded. Exceeding care will have to be used in making all joints, for if any leakage should reach the bilge and if the oil should then rise through the flooding of the bilges to the level of the fireroom plates the safety of the vessel might be endangered.

In the case of passenger and freight steamers, the vessels are of sufficient length to permit the main supply of oil to be carried in an expansion trunk or bunker extending the full width of the ship. It is also possible to have a cofferdam both forward and aft of this bunker, and thus leakage is quickly detected before such leakage has a chance to reach the double bottoms under the firerooms.

THE SMOKE NUISANCE.

One of the principal reasons heretofore advanced for the general use of oil rather than coal, as a fuel for naval purposes was the advantage that would accrue from the abolition of smoke. It seemed to be regarded as a matter of certainty, that with the use of oil, complete combustion of the fuel could be secured before the gases reached the base of the funnel. Possibly three-fourths of those who advocated the substitution of oil for coal, as a fuel for naval purposes, had not the slightest doubt but that the prevention of smoke would, thereby, be as certain as the obliteration of refuse in the ash pan.

There was hardly a naval writer who, in discussing the probable advance in naval construction, did not dwell upon the early prospect of dispensing with coal, and of the advantage that would ensue in having a fleet maneuver or establish a blockade, using such an incomparable smokeless fuel as crude oil. There were some naval strategists who regarded this advantage as one of the most important advances that would ensue in matters pertaining to naval engineering during the coming decade.

Where the oil used has passed through several stages of refining, and wherever a limited amount of oil is burnt in an exceedingly regular and uniform manner, then where an adequate and regular supply of air requisite for combustion is furnished, no smoke need appear. The ordinary household lamp may be regarded as an appliance for burning oil wherein all these necessary chemical and natural conditions are fulfilled.

On shore it is possible to approximate to many of the necessary conditions essential for securing complete combustion in the burning of oil, for in the installation of a land boiler there are but few limitations as to weight, floor space, or height. In arranging a battery of land boilers there can be effected such an installation that the management of the firing can be absolutely controlled by some intelligent and competent water tender. The height of the stack need only be limited by the judgment of the engineer who designed the plant. And yet on shore the burning of oil, as fuel, in large quantities has been carried on only with extreme difficulty as regards smoke, particularly when there has been an attempt made to force the fires.

An examination of the remarks made in connection with the different oil-fuel tests of the board will show that whenever an attempt was made, under severe forced-draft conditions, to secure an exceeding large evaporative capacity, the smoke nuisance was encountered. By an arrangement of mirrors, the condition of affairs as regards smoke, at the top of the stack, was always under observation by the water tender; and the ability to make such observation was of inestimable benefit in calling attention to the condition, and thus leading to a readjustment of burners to secure a reduction of the smoke nuisance.

Careful and long-continued observations upon the question of preventing smoke, convinced the board that with the use of water-tube boilers, as compared with the fire-tube boilers, the difficulty of effecting complete combustion before the gases reached the base of the stack had enormously increased. The result of investigating the smoke problem, only confirms the following opinion, formed by the study of the question of the efficiency of water-tube boilers, and that is that the weakness of the modern water-tube boiler lies in its inefficient system of baffling. This baffling is of such a nature, that it is almost impossible, under heavy forced-draft conditions, for complete combustion to be effected within the proper places, or for low stack temperature to be secured.

The burning of 40 pounds of coal per square foot of grate, or 25 pounds of oil per square foot of sectional furnace area, should be demanded in boilers of the modern battle ship. The great cost of these war ships, approximating over $7,500,000, combined with the fact that these vessels are primarily built for the day of battle, makes it absolutely necessary, that the boilers should be capable of severe forcing. It is also essential that their endurance under varied conditions should continue for at least six years after commissioning. The abolition of the smoke nuisance, when either coal or oil is used as a fuel, or when the consumption is forced beyond 40 pounds of coal per square foot of grate, or an equivalent consumption of oil; will probably never be accomplished for extended work, until more space is given for the installation of boilers and fewer limitations are placed upon the weight and height of these appliances. The firerooms of the present battle ship are so crowded with auxiliaries, and these auxiliaries are expected to serve so many purposes, that practically every condition for ideal firing, as compared with the land installation of boilers has been obliterated.

The existence of the smoke nuisance alone should cause naval experts to investigate the question, as to whether the time has now arrived; when a saving of weight effected by the removal of luxuries installed above the protective deck will not permit such space and weight thus gained to be assigned to an improvement of the boiler installation. Thus would it not be possible to secure more complete combustion of the fuel under forced-draft conditions?

In the attempt to prevent the smoke nuisance on board the war ship, particularly where oil is used as a fuel, it should be kept in mind that the installing of the boilers in different compartments produces different steaming conditions in the several stokeholds, owing to the greater ease with which air finds its way into some compartments as compared with others. Every marine engineer of experience knows that by reason of their location certain boilers steam more freely than others.

That there is a difference in the natural air supply of the several fireroom compartments, is evidenced by the fact that the fireroom force always find when the ship is under steaming conditions, that certain compartments are more habitable than others. By reason of the structural arrangement of the ship, it will probably be found impossible for the water tenders in the various compartments to observe whether or not smoke is issuing from the funnel of the several boilers under their charge. Where several boilers discharge the products of combustion into one funnel, the problem is still further complicated. Inspection of the flame through peepholes in the furnace front is less satisfactory for detecting smoke than a glance at the funnel top. In view of the extended experience acquired in the conduct of these oil tests, it can be safely affirmed, that in war ships fitted with protective decks, with an installation of water-tube boilers under forced-draft conditions, the smoke nuisance is likely to prove more obnoxious with the use of oil than with the use of coal as a fuel.

It is hopeless to expect an improvement in this respect until naval experts are ready to sacrifice either some of the luxuries or a small amount of the armor, so that the gain in weight secured thereby, will permit the lengthening of the ship to a degree that would not only permit more floor space, but allow additional weight for the installation of the battery of boilers. A simple change in the form of the arch of the protective deck, might, in some cases greatly improve matters, since this change would permit a much desired increase of height for installation of boilers and also render possible the introduction of some form of economizer that might be fitted in the uptake.

The chemistry of combustion is exceedingly simple. In order to secure the proper supply of air for consumption in naval boilers, there must be fewer limitations as to the manner in which the air supply shall be obtained. The openings and air passages to the stokeholds are too few and too small. The danger from collision has been exaggerated; and if the fact were kept in mind, that for every sailor who lost his life from such cause there were at least two firemen who died from causes incident to heat prostration; the question of ventilation, and of air supply to the firerooms, would be regarded more in connection with the problems of securing boiler efficiency and endurance as well as of mitigating the smoke nuisance.

In connection with this matter of obliterating smoke, it should be stated that although the board had the advice and assistance of the most experienced fuel experts in the United States in devising means to secure complete combustion, never in the experience of many citizens of Washington, had such clouds of smoke been seen coming from a chimney as issued from the boiler stack of the experimental plant when oil tests were conducted under strong forced-draft conditions. The smoke issuing from the stack during certain forced-draft tests was made a matter of official complaint by the civil authorities, and repeated warnings were given that the naval officials who were responsible for creating this excessive smoke nuisance, would be subjected to the penalty imposed by statute law.

As a matter of fact, none of the inventors of liquid-fuel appliances had ever encountered boiler conditions approximating to those demanded of a naval boiler in time of battle. Despite the extended shore experience of these experts, and the fact that an opportunity was given to them to improve matters, they were helpless to suggest a remedy. The fault could not be laid to the lack of skill of the crew of the U. S. S. *Rodgers*, for the visiting experts gave unqualified testimony as to the competency of these men. The production of such smoke could not be ascribed to the special design of the experimental boiler, for the results secured during this extended series of tests show that the design is among the best of the marine type, whether viewed from the standpoint of economy, capacity, or endurance.

The primary cause of the failure to secure complete combustion was due to the fact that too many limiting conditions are placed upon the designers of all marine boilers. In fact, the boilers have been too long regarded as tanks, whose installation and operation can be efficiently conducted in extremely limited space. The more one studies the naval-boiler problem, the more surprised he is at the high degree of boiler efficiency already attained, after contemplating the limited facilities for operation, examination, and repair.

The Board desires to emphasize the fact that the opinion thus expressed as regards the difficulty of preventing smoke issuing from the top of the funnel, when there is a heavy consumption of oil under severe forced draft conditions, applies specially to naval water tube boilers. These are the conditions that would prevail on board the war ship during the day of battle, for at such time every boiler would be forced to its utmost.

The increased space allowed for the installation of boilers in ships of the mercantile marine ought to cause conditions to be much more favorable to the obliteration of smoke where there is a use of oil fuel. In land boilers the conditions ought to be still more favorable to the smokeless burning of oil fuel, particularly where the consumption of fuel per square foot of heating surface is not excessive.

In brief, the smoke question will exist proportionately to the limitations which are placed upon the design and installation of boilers, and thus the problem of obliterating smoke in land boilers ought to be comparatively easy of solution in contrast to the eradication of the evil in boilers of naval vessels.

GENERAL SCOPE AND DETAILED MANAGEMENT OF EXPERIMENTS OPEN TO THE INSPECTION OF TECHNICAL MARINE EXPERTS.

From the commencement of the experiments the board established the policy of permitting anyone directly or indirectly interested in maritime or naval affairs to observe the conduct of the test. Hundreds of persons were requested, and many accepted the invitation, to witness the manner of carrying on the experiments. Scores of experts representing commercial, manufacturing, maritime, and naval interests spent hours at the plant. As it was recognized that it was not possible to withhold for any length of time any data that others might have a special interest in procuring, particularly as the experimental boiler was the property of a private corporation, there was no attempt to attach either mystery or importance to the work.

The board unreservedly arranged for the taking of all data and for determining the character and extent of the tests. Anyone directly or indirectly interested in the boiler, or in any mechanical appendage or auxiliary used in connection with the plant, was permitted to take a copy of the observed data. The only condition imposed in regard to the collection of information by others was that there should be no interference with the conduct of the experiments.

There was not an individual associated with the tests who did not become exceedingly interested in the work, and all were receptive for any information or advice that would tend to secure important and reliable data. These tests ought, therefore, to stand for all time as evidence of the intelligence and fairness of the Navy Department in the conduct of official tests of appliances relating to the naval service. It is believed that no more complete or exhaustive oil-fuel tests have ever been conducted under naval auspices, and it is doubtful if either in extent or reliability they have ever been equaled by either private or corporate interests.

There was but one complaint made as to the manner in which the tests were conducted, and that was from an inventor who, after having been granted two weeks to install his appliance and make preliminary tests, demanded additional time for experimental purposes. The request was denied, because any attempt upon the part of a single individual to use the experimental plant as a means of developing and perfecting special appliances not only subjected other inventors to delay and expense, but tended to abridge the scope of the experiments projected. It is only necessary to state in this special instance, that until the crew of the U. S. torpedo boat *Rodgers* suggested details in the installation of this special burner, its inventor was unable to secure any substantial or satisfactory results, either as regards economical efficiency, or evaporative capacity.

NECESSITY OF RAPIDLY AND CLOSELY REGULATING THE ADMISSION OF AIR REQUISITE FOR COMBUSTION.

Where oil is used as a fuel, there should be determined, by practical experiment for various conditions, the size of openings in ash pits requisite for admitting air essential for completing combustion. In the use of liquid fuel there will always be a tendency to admit too much air, and this should be checked by the installation of a series of dampers whose opening could be closely regulated.

Where coal is used on the grates, such fuel remains for an appreciable interval of time on the bars, and thus checks the passage of air from the ash pit. The bed of incandescent fuel thus limits the amount of air that will reach the combustion chamber.

Where oil is used as a fuel there is no corresponding interference with the draft from the ash pit. On the contrary, the heating of the air increases the velocity of the current. The reduction in the time available for the diffusion of the particles of oil with the air undoubtedly more than offsets the advantage due to the rapidity with which the subdivision of the oil particles is effected.

One of the principal problems in successful oil burning will thus be, to impede the flow of the gases so that complete diffusion of the particles of oil will take place in the combustion chamber and amid the tubes. Such devices as bridge walls, arches, deflectors, baffles, and other forms of furnace construction undoubtedly check in part the flow of the gases. The difficulty of impeding the flow of the gases will, therefore, prevent the economical installation of oil burners in special forms of bent water-tube boilers. It is probable that oil-fuel installations in marine water-tube boilers will be limited to those types which admit of extensive baffling.

Precautions should also be taken that large volumes of air are not suddenly admitted to the furnace; otherwise these cold currents will cause soot to be deposited on the surfaces of the boiler.

Where too much cold air is admitted above the burners, through the furnace front, there is a tendency to produce noise; in some cases there will be resulting explosions, sufficient to shake the boiler casings. The problem, therefore, as to the quantity of air which should be admitted for completing combustion, as well as the manner of admission of this air, will have a very important effect in many ways, upon the satisfactory use of oil as a fuel, either for manufacturing or marine purposes.

INFLUENCE OF HYGROMETRIC CONDITION OF THE ATMOSPHERE AS REGARDS EFFICIENCY AND CAPACITY.

The oil-fuel experiments had been conducted but a short period before it was observable that the hygrometric state of the atmosphere had an important influence upon, both, evaporative efficiency, and evaporative capacity.

That the humidity of the atmosphere is a determining factor as regards evaporative efficiency was specially demonstrated during test No. 15, of October 4, 1902, in the log of which appears the following remarks:

> This test was intended to be a reproduction of that of September 22, and was to develop a possible correction to be applied to the records of September 19, 20, and 22, on account of the dirty condition of the boiler during those tests (it having since been blown down and the tubes cleaned of soot).
>
> With the same air openings into the furnace as on September 22, and with almost exactly the same percentage of steam used for spraying the oil, it was impossible to burn more than 84 per cent of the oil burned then. This can be accounted for only by the difference in hygrometric condition on the two days, the air on this run being saturated. This suggests the advisability of adding the hygrometric condition of the atmosphere to the data recorded for each run.

In the investigation of this matter both efficiency and capacity curves were plotted and compared with humidity curves for the periods covered by several tests. In each case the influence of humidity was specially noted. It is therefore reasonable to infer that when operating a boiler at a given capacity the efficiency varies inversely with the humidity.

The decrease of efficiency due to humidity can be ascribed to two causes—

First. To the displacement of a certain amount of oxygen in a given volume of air by the moisture of the atmosphere, thus requiring an excess in volume of air for completing combustion, with consequent loss of heat in the stack.

Second. To the decreased rapidity of diffusion of the combustible gases with the oxygen due to the presence of the inert moisture.

The abrupt termination of the oil tests prevented the special investigation of the influence of humidity of the atmosphere both as regards the evaporative efficiency and evaporative capacity of the experimental boiler. In making comparisons between different boilers it is thus essential that the hygrometric conditions of the atmosphere during the several tests be taken into consideration.

WHERE OIL IS USED AS FUEL THE HIGHEST CHARACTER OF INSTALLATION MUST BE EFFECTED.

The board was strikingly impressed with the fact that it will be found essential where oil is used as a fuel to effect the highest character of installation. All contemplating the use of such a fuel, should regard the building of storage tanks as a boilermaker's job, and not as a work that should be intrusted to either a cooper or a tank builder. The first cost of a boilermaker's job, as regards tank construction may seem excessive as compared with the expense of having it done by manufacturers of ordinary steel tanks. It is certain, however, that increased economy and safety will result from such an installation.

The introduction of all burners and their necessary piping, should likewise be intrusted only to expert steam fitters possessing considerable experience and knowledge of the action of crude patroleum vapors. The remarkable searching and destructive power of petroleum gases, will be evidenced to the users of oil fuel, if any cheap installation of appliances is attempted.

As it will be imperative to maintain an oil-fuel plant in the highest state of efficiency, the actual cost of upkeep of plant using oil as compared with coal will not be as economical as has been maintained. For a time an oil-fuel plant may be operated by cheap labor, but the continued employment of such men will invite disaster.

In regard to fuel-oil storage on ocean-going steamers, an observance of the following general rules will prove exceedingly beneficial to ship owners, as well as those called upon to operate the plant. The board is indebted to Mr. J. B. Warner, the Pacific coast representative of the Hartford Steam Boiler Inspection and Insurance Company, for valuable information in regard to the methods of successful installation on many steamers of the Pacific coast, and simple as the following rules are, they represent extended study and experience of many users.

For small independent tanks, not forming part of the double bottom, and which tanks are not more than four feet in height, the shell plates should be of steel of good quality and heavy enough to prevent the seams being opened by the motion of the ship or surging of the oil in any weather. It is recommended that for ocean steamers the shell plates of these tanks be five-sixteenths of an inch in thickness and for inland steamers one-fourth of an inch in thickness. Where tanks of greater heights are contemplated, Lloyd's or other rules as applicable, to water-tight bulkheading should be used.

The seams of large cylindrical tanks should be double chain riveted, sheets laid close and well calked.

It is also recommended that the rivet holes be drilled instead of punched. They will then be fair, and rivets can be driven to properly fill the holes to prevent leakage.

In long tanks, suitable baffling or swash plates should be put in and securely fastened, to prevent the oil from surging. Under each small tank, when the tank is separate from the ship's structure, there is required to be a drip pan. This should be of lead weighing not less than 8 pounds to the square foot.

In deep tanks, when forming part of the structural portion of the vessel, special attention should be given to the proper and ample proportioning of the bulkhead stiffeners.

There should be no openings cut into the bottom, sides, or ends of the tanks; all inlets and outlets must be through the top.

Reenforcing flanges should be of wrought steel and properly riveted to the top of the tank for filling, suction, and vent pipes. All filling pipes should run to the bottom of the tanks, so that when the tanks are filled the gas will be expelled through the vent pipes.

The man-plate opening should be of ample size (11 by 16 inches may do) to facilitate getting into the tank for any purpose. The vent must have an area equal to the diameter of the filling pipe, and should be carried up above the superstructure of the vessel and have a non-return bend on the end and covered with a fine copper-wire-gauze screen.

No fuel oil is allowed to be carried in the water bottoms under the engine or boiler rooms on steamers.

"Davie" safety lamps should be provided for engineers and for all directly employed in the firerooms, so that if the electric-light plant is shut down they can be used in place of an open-flame lamp. The regulations of the United States Steamboat-Inspection Service require that for oil burning on freight vessels there shall be valves fitted in the connection between the supply tank and the boiler. With such a valve installed the flow of oil at all times can either be regulated or cut off in case it is desired to extinguish or check the fire. Where more than one tank is used for stowage of oil, and such tanks are connected for discharge of oil from one tank to another, arrangements must be made whereby such valves can be manipulated from the main deck of the steamer.

While the number of oil-fuel installations for marine work has greatly increased during the past two years, increased consideration is being given the question of safety. It is in the direction of making such plants more safe rather than more economical that extended improvement should now be made.

THERMAL EFFICIENCY NOT INCREASED BY THE USE OF STEAM.

There is a widespread misconception regarding the part that the steam which is used for atomizing purposes plays in effecting combustion. It is supposed by many, that after atomizing the oil, the steam is decomposed and that the hydrogen and carbon are again united, thus producing heat and adding to the heat value of the fuel. While it may be true that the presence of steam may change the character and sequence of the chemical reaction and result in the production of a higher temperature at some part of the flame, such an advantage will be offset by lower temperatures elsewhere between the grate and the base of the stack. All steam that enters the furnace will, if combustion is complete, pass up the stack as steam, also carrying with it a certain quantity of waste heat. The amount of this waste heat will depend upon the amount of steam and its temperature at entrance of the furnace. The quantity of available heat, measured in thermal units, is undoubtedly diminished by the introduction of steam. In an efficient boiler it is quantity of heat rather than intensity that is wanted. For many manufacturing purposes intensity of heat may be of primary importance, but in a marine steam generator a local intense heat is objectionable on other grounds than those of economy, viz, its liability to cause leaky tubes and seams from the unequal expansion of heating surfaces.

NAVAL RESEARCH SHOULD BE CONDUCTED ENTIRELY BY PERSONS WITHIN THE NAVY.

The board desires to state that such experiments can not be conducted to the best interest of the service without the aid of a navy crew of firemen and observers. It is essential that the board should be able to call upon such crew for either day or night work. While most of the official tests were only of eight hours' duration, it required several hours to warm up the boiler and get things in good running shape. Then it requires one or two hours after the completion of the test to secure the plant and guard against fire.

A civilian crew will only work eight hours, and then at stated intervals. They demand extra compensation for overtime, and it is no easy matter to get them to stand up to forced-draft conditions, particularly when the higher air pressures are used. A crew of firemen that is changed from day to day, and who are apprehensive of their personal safety when forced-draft trials are made, can not be interested in the work. The experiences of the Oil City Boiler Works for over a year in the conduct of the coal experiments show excessive trouble, annoyance, expense, and delay arising from attempting to use such employees in experimental research.

The experimental crew must be under military control and discipline, and this can only be secured by having some vessel of the Navy, regularly in commission, assigned to duty in connection with an experimental board.

The data submitted will best tell the work done during the past two years, by the complement forming the testing staff. Which work and results were at all times carefully supervised by the personnel of the board, every member of which had other duties to perform as an official of the Bureau of Steam Engineering. In the collection of such data it is the character and quality rather than the quantity which the engineering world desires.

THE WORLD'S RELATIVE PRODUCTION OF COAL AND CRUDE PETROLEUM.

A careful study of the latest reports of the United States Geological Survey, will show the relatively small production throughout the world, of crude petroleum as compared with coal. It is exceedingly important to note likewise that, judged from a naval standpoint, the distribution of the coal beds is much more extensive, and therefore much more advantageously located than that of the oil fields. This distribution of the world's fuel supply should be given special consideration in the study of the military phase of the oil-fuel problem.

When it is considered that crude petroleum is extensively used in the arts and sciences, as well as for lubricating and illuminating purposes, it is probable that less than one-half of the world's production of crude petroleum is available for fuel. Regarding 3 to 3½ barrels of oil as the equivalent of 1 ton of coal, it will be observed, from a comparison of the following tables, *that less than three per cent of the world's production of fuel can possibly be secured from the use of crude petroleum.*

Independent of the question of cost, the use of oil as fuel for either manufacturing, maritime, or naval purposes must therefore for a time be considered as limited, by reason of the shortness of supply.

While Russia produces about 44 per cent of the world's output of petroleum, her oil fields are not located advantageously for use, either by her navy, or by foreign commerce. From a military standpoint, the United States, which produces 48 per cent of the world's output, is the only naval power which could hope to utilize to any great extent this incomparable fuel for naval and maritime purposes. This is because the Texas and California oil fields are within comparatively short distances of greal maritime ports and possible scenes of naval operations.

WORLD'S PRODUCTION OF COAL.

In the following table, prepared by the United States Geological Survey, is given the coal production of the principal countries, for the years nearest the one under review, for which figures could be obtained. For the sake of convenience the quantities are expressed in the unit of measurement adopted in each country, and reduced for comparison to short tons of 2,000 pounds. In each case the year is named for which the production is given:

Country and usual unit.	Quantity.	Equivalent in short tons of 2,000 pounds.
United States (1902) ....long tons..	269, 277, 178	301, 590, 439
Great Britain (1902) ....do....	277, 095, 042	310, 346, 447
Germany (1902) ....metric tons..	150, 436, 810	165, 826, 496
Austria-Hungary (1901) ....do....	41, 202, 902	45, 417, 959
France (1902)...............................do....	30, 196, 994	33, 286, 146
Belgium (1901) ....do....	22, 213, 410	24, 485, 842
Russia (1901) ....do....	16, 269, 800	17, 934, 201
Canada (1902) ....short tons..	7, 639, 225	7, 639, 225
Mexico (1902).....................metric tons..	709, 654	782, 251
Japan (1900) ....do....	7, 429, 457	8, 187, 262
India (1902)...........................long tons..	7, 433, 972	8, 326, 049
New South Wales (1902) ....do....	5, 942, 011	6, 655, 052
Spain (1901).........................metric tons..	2, 747, 724	3, 027, 992
New Zealand (1901) ....long tons..	1, 227, 638	1, 374, 955
Sweden (1902)......................metric tons..	304, 733	335, 907
Italy (1901) ....do....	425, 614	469, 154
Holland (1900) ....do....	320, 225	352, 888
South African Republic (1901)...........long tons..	671, 532	752, 116
Queensland (1901) ....do....	539, 472	604, 209
Victoria (1901) ....do....	209, 329	234, 418
Natal (1902).................................do....	592, 821	663, 960
Cape Colony (1900) ....do....	198, 451	222, 265
Tasmania (1900) ....do....	43, 010	48, 171
Other countries[a]............................do....	2, 000, 000	2, 240, 000
Total	....	940, 803, 434
Percentage of the United States	....	32

---

[a] Includes China, Turkey, Servia, Portugal, United States of Colombia, Chile, Borneo and Labuan, Peru, Greece, etc.

WORLD'S PRODUCTION OF CRUDE PETROLEUM.

The following table gives the production, approximately, of crude petroleum in all of the known countries of the world, together with the percentages of each for 1901 and 1902, in terms of United States barrels, at 42 gallons per barrel of 231 cubic inches per gallon. A small estimated quantity has been placed under the head of "all other countries." This quantity includes a primitive production in several of the South American States, Algeria in Africa, Persia, the Philippines, and China, from which no returns could be secured.

The total increase in 1902 amounted to almost 12 per cent as compared with 1901 and to almost 25 per cent as compared with 1900. The most conspicuous items in the list are the increase in the production of the United States and the decrease in the production of Russia, the United States, for the first time in five years, surpassing Russia in production by 8,226,871 barrels. The United States and Russia produced, in 1902, 91.44 per cent of the total output as compared with 93.22 per cent in 1901 and with 94.11 per cent in 1900. Of the remaining 8.56 per cent, Sumatra, Java, Borneo, Galicia, and Roumania, which furnished only 4.65 per cent in 1901, furnished 6.52 per cent in 1902, leaving 2.04 per cent of the total as the output of all the other producing countries.

World's production of crude petroleum in 1901 and 1902. [a]

Country.	1901.		1902.	
	Quantity in barrels of 42 United States gallons.	Percentage of total.	Quantity in barrels of 42 United States gallons.	Percentage of total.
United States	69, 389, 194	41. 84	88, 766, 916	47. 94
Canada	572, 500	. 35	520, 000	. 28
Peru	72, 261	. 04	60, 000	. 03
Russia	85, 168, 556	51. 38	80, 540, 045	43. 50
Galicia	3, 251, 544	1. 96	4, 142, 160	2. 24
Sumatra, Java, and Borneo	3, 038, 700	1. 84	5, 860, 000	3. 17
Roumania	1, 406, 160	. 85	2, 059, 930	1. 11
India	1, 430, 716	. 86	1, 617, 363	. 87
Japan	1, 100, 000	. 67	1, 193, 000	. 64
Germany	313, 630	. 19	353, 675	. 20
Italy	10, 100	. 02	12, 000	. 02
All other countries	20, 000		26, 000	
Total	165, 773, 361	100. 00	185, 151, 089	100. 00

[a] Report United States Geological Survey.

PRODUCTION OF CRUDE PETROLEUM IN UNITED STATES FROM 1859 TO 1902, INCLUSIVE.

In the following table will be found a statement of the production of crude petroleum in the United States from the beginning of production, marked by the drilling of the Colonel Drake well in 1859, up to and including the production of 1902, the table being by years and States.

Production of crude petroleum in the United States, 1859–1902, by years and by States.

[Barrels of 42 gallons.]

Year.	Pennsylvania and New York.	Ohio.	West Virginia.	California.	Kentucky and Tennessee.	Colorado.	Indiana.
1859	2,000	....	....	....	....	....	....
1860	500,000	....	....	....	....	....	....
1861	2,113,609	....	....	....	....	....	....
1862	3,056,690	....	....	....	....	....	....
1863	2,611,309	....	....	....	....	....	....
1864	2,116,109	....	....	....	....	....	....
1865	2,497,700	....	....	....	....	....	....
1866	3,597,700	....	....	....	....	....	....
1867	3,347,300	....	....	....	....	....	....
1868	3,646,117	....	....	....	....	....	....
1869	4,215,000	....	....	....	....	....	....
1870	5,260,745	....	....	....	....	....	....
1871	5,205,234	....	....	....	....	....	....
1872	6,293,194	....	....	....	....	....	....
1873	9,893,786	....	....	....	....	....	....
1874	10,926,945	....	....	....	....	....	....
1875	8,787,514	[a] 200,000	[a] 3,000,000	[a] 175,000	....	....	....
1876	8,968,906	31,763	120,000	12,000	....	....	....
1877	13,135,475	29,888	172,000	13,000	....	....	....
1878	15,163,462	38,179	180,000	15,227	....	....	....
1879	19,685,176	29,112	180,000	19,858	....	....	....
1880	26,027,631	38,940	179,000	40,552	....	....	....
1881	27,376,509	33,867	151,000	99,862	....	....	....
1882	30,053,500	39,761	128,000	128,636	[b] 160,933	....	....
1883	23,128,389	47,632	126,000	142,857	4,755	....	....
1884	23,772,209	90,081	90,000	262,000	4.148	....	....
1885	20,776,041	661,580	91,000	325,000	5,164	....	....
1886	25,798,000	1,782,970	102,000	377,145	4,726	....	....
1887	22,356,193	5,022,632	145,000	678,572	4,791	76,295	....
1888	16,488,668	10,010,868	119,448	690,333	5,096	297,612	....
1889	21,487,435	12,471,466	544,113	303,220	5,400	316,476	33,375
1890	28,458,208	16,124,656	492,578	307.360	6,000	368,842	63,496
1891	33,009,236	17,740,301	2,406,218	323,600	9,000	665,482	136,634
1892	28,422,377	16,362,921	3,810,086	385,049	6,500	824,000	698,068
1893	20,314,513	16,249,769	8,445,412	470,179	3,000	594,390	2,335,293
1894	19,019,990	16,792,154	8,577,624	705,969	1,500	515,746	3,688,666
1895	19,144,390	19,545,233	8,120,125	1,208,482	1,500	438,232	4,386,132
1896	20,584,421	23,941,169	10,019,770	1,252,777	1,680	361,450	4,680,732
1897	19,262,066	21,560,515	13,090,045	1,903,411	322	384,934	4,122,356
1898	15,948,464	18,738,708	13,615,101	2,257,207	5.568	444,383	3,730,907
1899	14,374,512	21,142,108	13,910,630	2,642,095	18,280	390,278	3,848,182
1900	14,559,127	22,362,730	16,195,675	4,324,484	62,259	317,385	4,874,392
1901	13,831,996	21,648,083	14,177,126	8,786,330	137,259	460,520	5,757,086
1902	13,183,610	21,014,231	13,513,345	13,984,268	185,331	396,901	7,480,896
Total	628,401,456	283,751,317	131,701,296	41,834,473	633,212	6,852,926	45,896,215

[a] Includes all production prior to 1876.
[b] Includes all petroleum produced in Kentucky and Tennessee prior to 1883.

Production of crude petroleum in the United States, 1859–1902, etc.—Continued.

Year.	Illinois.	Kansas.	Texas.	Missouri.	Indian Territory.	Wyoming.	Louisiana.	United States.
1859	....	....	....	....	....	....	....	2,000
1860	....	....	....	....	....	....	....	500,000
1861	....	....	....	....	....	....	....	2,113,609
1862	....	....	....	....	....	....	....	[a]3,056,690
1863	....	....	....	....	....	....	....	2,611,309
1864	....	....	....	....	....	....	....	2,116,109
1865	....	....	....	....	....	....	....	2,497,700
1866	....	....	....	....	....	....	....	3,597,700
1867	....	....	....	....	....	....	....	3,347,300
1868	....	....	....	....	....	....	....	3,646,117
1869	....	....	....	....	....	....	....	4,215,000
1870	....	....	....	....	....	....	....	5,260,745
1871	....	....	....	....	....	....	....	5,205,234
1872	....	....	....	....	....	....	....	6,293,194
1873	....	....	....	....	....	....	....	9,893,786
1874	....	....	....	....	....	....	....	10,926,945
1875	....	....	....	....	....	....	....	[b]12,162,514
1876	....	....	....	....	....	....	....	9,132,669
1877	....	....	....	....	....	....	....	13,350,363
1878	....	....	....	....	....	....	....	15,396,868
1879	....	....	....	....	....	....	....	19,914,146
1880	....	....	....	....	....	....	....	26,286,123
1881	....	....	....	....	....	....	....	27,661,238
1882	....	....	....	....	....	....	....	30,510,830
1883	....	....	....	....	....	....	....	23,449,633
1884	....	....	....	....	....	....	....	24,218,438
1885	....	....	....	....	....	....	....	21,858.785
1886	....	....	....	....	....	....	....	28,064,841
1887	....	....	....	....	....	....	....	28,283,483
1888	....	....	....	....	....	....	....	27,612,025
1889	1,460	500	48	20	....	....	....	35,163,513
1890	900	1,200	54	278	....	....	....	45,823,572
1891	675	1,400	54	25	30	....	....	54,292,655
1892	521	....	45	10	80	....	....	50,509,657
1893	400	18,000	50	50	10	....	....	48,431,066
1894	300	40,000	60	8	130	2,369	....	49,344,516
1895	200	44,430	50	10	37	3,455	....	52,892,276
1896	250	113,571	1,450	43	170	2,878	....	[c]60,960,361
1897	500	81,098	65,975	19	625	3,650	....	[c]60,475,516
1898	360	71,980	546,070	10	....	5,475	....	[c]55,364,233
1899	360	69,700	669,013	[b]132	....	5,560	....	[c]57,070,850
1900	200	74,714	836,039	[d]1,602	6,472	5,450	....	63,620,529
1901	250	179,151	4,393,658	[e]2,335	10,000	5,400	....	69,389,194
1902	200	331,749	18,083,658	[e]857	37,000	6,253	548,617	88,766,916
Total	6,576	1,027,493	24,596,224	5,399	54,554	40,490	548,617	1,165,290,248

---

[a] In addition to this quantity it is estimated that for want of a market some 10,000,000 barrels ran to waste in and prior to 1862 in the Pennsylvania fields; also a large quantity in West Virginia and Tennessee.

[b] Includes all production prior to 1876 in Ohio, West Virginia, and California.

[c] In addition to this quantity, 4,325 barrels of crude oil were produced in Kentucky and Tennessee in 1896, 4,377 barrels in 1897, 19,125 barrels in 1898, and 13,578 barrels in 1899, for which, as none was sold or used, no value could be given.

[d] Includes the production of Michigan.

[e] Includes production of Michigan and small production in Oklahoma Territory.

The total output of crude petroleum since it was first discovered in quantity, in 1859, by Colonel Drake, on the waters of Oil Creek, near Titusville, Pa., to the end of 1902, amounted to 1,165,290,248 barrels. Allowing 5.6 cubic feet for 1 barrel, this quantity of petroleum would occupy 6,525,625,389 cubic feet of space, which would require a cube 1,868½ feet on each side to contain it. It would fill a tank whose base is one mile square to a height of 234 feet. It would likewise fill 38,843 tanks containing 30,000 barrels each. Allowing 90 feet for the diameter of tanks of this size, if they were placed so that their sides would touch, they would reach a distance of 662 miles; or again, if 2½ feet be allowed for the height of a barrel, and if these barrels, filled with all the domestic oil that has been produced, were laid so that their heads would touch, they would encircle the earth 2.28 times. If we estimate 3½ barrels of petroleum as equal to 1 ton of average coal, we have a fuel equivalent represented by 332,940,071 tons of coal.

Of the grand total of the crude petroleum produced in the United States from the beginning, in 1859, to the end of 1902, Pennsylvania and New York produced 53.9 per cent; Ohio, 24.3 per cent; West Virginia, 11.3 per cent; Indiana, 3.9 per cent; California, 3.6 per cent; Texas, 2.1 per cent; leaving 0.9 per cent to be supplied by the States of Kansas, Colorado, Louisiana, Illinois, Missouri, Indian Territory, Wyoming, Michigan, and Oklahoma Territory.

PRODUCTION AND VALUE.[a]

PRODUCTION BY STATES AND FIELDS.

In the following table is given a statement of the total quantity, and the total value, of all crude petroleum produced in the United States in 1901 and 1902, by States and important districts:

Total quantity and value of crude petroleum produced in the United States and average price per barrel in 1901 and 1902.

State and district.	1901.			1902.		
	Quantity.	Value.	Average price per barrel.	Quantity.	Value.	Average price per barrel.
	Barrels.			*Barrels.*		
California	8,786,330	$4,974,540	$0.566	13,984,268	$4,873,617	$0.348
Colorado	460,520	461,031	1.00	396,901	484,683	1.22
Illinois	250	1,250	5.00	200	1,000	5.00
Indiana	5,757,086	4,822,826	.8377	7,480,896	6,526,622	.872
Indian Territory	10,000	7,125	.7125	37,000	32,190	.87
Kansas	179,151	154,373	.862	331,749	292,464	.88
Kentucky and Tennessee	137,259	111,527	.813	185,331	141,044	.76
Louisiana	....	....	....	548,617	188,985	.344
Michigan Missouri Oklahoma Territory	2,335	2,600	1.1135	857	1,816	2.12
New York	1,206,618	1,460,008	1.21	1,119,730	1,530,852	1.367

---

[a] Report United States Geological Survey.

Total quantity and value of crude petroleum produced in the United States, etc.—Cont'd.

State and district.	1901.			1902.		
	Quantity.	Value.	Average price per barrel.	Quantity.	Value.	Average price per barrel.
Ohio:	*Barrels.*			*Barrels.*		
Eastern and southern	5,470,850	6,619,342	1.21	5,136,366	6,471,821	1.26
Lima	16,176,293	13,911,612	.86	15,877,730	14,284,072	.899
Mecca-Belden	940	2,617	2.78	135	1,466	10.86
Total	21,648,083	20,533,571	.948	21,014,231	20,757,359	.988
Pennsylvania:						
Franklin	55,162	220,648	4.00	50,555	199,432	3.945
Pennsylvania	12,568,806	15,208,255	1.21	12,012,125	15,064,861	1.254
Smiths Ferry	1,410	1,706	1.21	1,200	1,800	1.50
Total	12,625,378	15,430,609	1.222	12,063,880	15,266,093	1.265
Texas	4,393,658	1,247,351	.284	18,083,658	3,998,097	.2211
West Virginia:						
West Virginia	14,164,662	17,139,241	1.21	13,498,685	17,006,469	1.26—
Petroleum Volcano	[a] 12,464	33,483	2.687	[a] 14,660	33,848	2.309
Total	14,177,126	17,172,724	1.211	13,513,345	17,040,317	1.261
Wyoming	5,400	37,800	7.00	6,253	43,771	7.00
Grand total	69,389,194	66,417,335	.957+	[b] 88,766,916	71,178,910	.8019

[a] Production of light oil in Petroleum included with West Virginia's production.
Production of light oil in Volcano included with West Virginia's production.

[b] In addition to this quantity, 76,538 barrels were produced in Kentucky, valued at $41,353; 489 barrels in Missouri, valued at $842, and 431,359 barrels in Texas, valued at $176,634, which were tanked and unsold by the producing companies. The total quantity produced but not sold in 1902 was 508,386 barrels, valued at $218,829; the total production in 1902, marketed and unmarketed, was therefore 89,275,302 barrels, valued at $71,397,739.

Production of crude oil in California for 1903.

[Reported by the California Petroleum Miners' Association.]

District.	Producing wells.	Production.
		Barrels.
Fullerton	138	250,000
Puente	80	100,000
Whittier	103	50,000
Los Angeles	984	900,000
Newhall and Ventura	325	900,000
Summerland	190	100,000
Santa Maria	24	1,000,000
Kern River	750	15,750,000
Sunset and Midway	120	250,000
McKittrick	76	1,700,000
Coalinga	115	2,600,000
Sargents	4	1,000
Halfmoon Pay	5	1,000
Total	2,914	23,602,000

THE OIL PRODUCTION OF THE UNITED STATES AVAILABLE FOR FUEL PURPOSES.

Careful consideration has been given the question as to the supply of crude petroleum in the United States available for fuel purposes. This matter has been specially investigated by Prof. Arthur L. Williston, of the Pratt Institute, Brooklyn, N. Y., who reports as follows:

> The supply of oil which is available for fuel in the United States, therefore, is, first, the small percentage (probably not over 2 or 3 per cent) of the total production of the Pennsylvania and Ohio oil—the residuum from the process of refining; second, crude oil from the Ohio and Indiana fields, wherever the price of coal makes the burning of oil at 95 cents or $1 per barrel (plus freight) profitable; third, those portions of the California oil which are not best suited for refining; fourth, practically the entire output of the Texas field.

The demands for the better grades of oil for refining purposes will probably keep pace with its production; consequently we can never expect to see such grades of oil compete with coal to any large extent.

On the other hand, the refining value of the Texas oil and much of the California oil is so low that its value will probably always be largely controlled by the demand for it for fuel purposes. It is inconceivable that a fuel which has so many distinct advantages, and which is not unlimited in its supply, should sell in all markets at a price which would make it cheaper to burn than coal. Any great demand for such a fuel would bring its price up at once.

On the other hand, so long as there is an assured supply of Texas and California fuel oil, the price of such oil that has little intrinsic value for refining, will probably remain low enough to enable it to compete successfully with coal, in those regions where coal is scarce in quantity and poor in quality. And the area in which this condition exists is sufficiently wide to create a demand for the fuel oil that will soon equal the supply, unless further stores of oil are found as the demand for it increases.

The fact should be remembered that in every oil region there is with each succeeding year a progressive proportionate increase in the percentage of the yield consumed for illuminating purposes.

ECONOMICAL ADVANTAGES OF AN OIL-FUEL INSTALLATION.

The relative evaporative efficiency of oil and coal as a fuel, as determined by this extended series of comparative experiments, is practically in the proportion of 15 to 10. The actual superiority of oil will be considerably greater, for in the coal experiments unusual skill was exercised in the management of the fires. Lump coal of superior quality was used; and as the tests with coal were of comparatively short duration, the resulting loss from cleaning fires was much less than would occur in actual service. The oil experiments, however, were carried on under conditions that more closely approximated those that could be secured on board the seagoing vessel. The actual evaporative efficiency of a pound of oil as compared with a pound of coal will therefore be in the ratio of 17 to 10, and these figures can be regarded as substantially correct.

It will be found, practically, that the thermal efficiency of a pound of oil is the same whether the oil be crude or refined. While the crude oils contain sulphur and other chemical elements that are low in thermal efficiency, they contain substances that are particularly rich in hydrogen. In the process of distillation not only the sulphur but the rich hydrocarbons are lost, and it can thus be expected that in the commercial burning of oil as a fuel, the evaporative efficiency of the same weight of oil fuel from every field or district will be practically the same.

From the standpoint of volume, therefore, it will be found that the highest evaporative results ought to be secured from the heaviest oil. As oil is sold by the gallon, and therefore by volume, the California product, from the fuel standpoint, ought thus to have an advantage over the yield from other fields. For some time, however, it can be expected that extra trouble and expense will be incurred in efficiently and uniformly burning heavy oils. There is not likely to be any actual advantage, therefore, from the use of heavy oils as viewed from the standpoint of weight of fuel.

Special experiments should be conducted to determine the best means of burning the heaviest of oils. The first distillation, however mild, is of great advantage in adapting crude petroleum as a fuel, since such slight refining not only reduces the explosive qualities of the oil, but materially decreases any liability of the oil to affect bunker or boiler plates injuriously. The solution of the problems of cost, as well as of transportation, will likewise be greatly aided by effecting this refining as close as possible to the wells. It would certainly seem that the refinery should not be placed beyond the end of the pipe line or terminal marine shipping point.

In noting the comparative economical efficiency, for naval purposes, of oil and coal, there must also be taken into consideration the fact that a ton of oil can be stowed in somewhat less space than a ton of bituminous coal. Then, again, it must be considered that in the carrying of oil the compartments can be more completely filled. The relative efficiency of oil and good steaming coal from the naval standpoint of fuel supply in war ships may thus be regarded as in the ratio of 18 to 10.

The board is therefore of the opinion, after special investigation of the comparative merits of coal and oil that, in regard to the evaporative efficiency, a long ton of the best quality of coal, such as Cardiff or Pocahontas coal, is equivalent to four and one-half barrels of oil; and that, in a long ton of an inferior quality of coal, the evaporative effect will be that obtained from only three to three and a half barrels of oil. This comparison is based upon the assumption that, until greater volume is permissible for the installation of naval boilers, it will not be possible to secure, in actual naval practice, an evaporation from and at 212° F. of over 14 pounds of water per pound of oil fuel. Increased efficiency, however, may be secured by heating the air requisite for combustion, as in the Howden or some similar system, whereby the heat of the escaping gases is utilized for raising the temperature of the entering air requisite for combustion.

THE EFFICIENCY AND ENDURANCE OF THE HOHENSTEIN BOILER.

The experimental boiler on which the extended series of coal and oil tests were made, was under the special observation of the board for a continuous period of twenty-seven months. During that time it was probably subjected to as severe usage as was ever applied to a marine water-tube boiler.

Eighty-six official tests were made—sixty-nine with oil and seventeen with coal. The first official coal test was made April 23, 1901, and the last oil test June 17, 1903. There were conducted at least another hundred, short preliminary, or unofficial trials. During some of the unofficial tests the boiler was subjected to irregular and unusual service, and therefore the general work to which it was submitted probably represents every practical condition under which a shore boiler would be operated. When the tests were completed, after twenty-seven months of experimentation the boiler had been subjected to more forced-draft pressure, exceeding 1 inch of water, than had been sustained by all the straight water-tube boilers in actual use in the American Navy during that period.

There is no doubt that, by reason of the design and size of the downcasts, the circulation of the water in this boiler is exceedingly uniform and certain under the severest of forced-draft conditions.

At the conclusion of the extended series of tests, every part of the boiler was carefully and critically examined by members of the board. Beyond the sweating of a calked seam, in the end of one of the mud drums, no leak was detected in the boiler. Portions of the linings of the casings were considerably burnt. There was no evidence that any of the tubes had sprung or buckled, and the baffling was found intact.

For feed purposes the ordinary muddy water of the Potomac had been used. There was seldom a week, during the two and one-half years, that the boiler was under trial, when at least one test was not made, and at no time was any owner of an oil burner required or permitted to delay a test on account of the condition of the water in the river.

At the end of the experiments the interior of the tubes was found coated with a very hard deposit of scale, strongly resembling cement paint in appearance and thickness. One large and one small tube were cut out and put upon a planer and cut in halves lengthwise to note whether there had been any grooving or corrosion. These tubes were selected from portions of the boiler, where it was presumed that the circulation was the poorest, and where the worst results could be expected. There was absolutely no evidence that there had been any appreciable change of appearance, of either exterior or interior surfaces, either from corrosion or from the impact of the flow of the gases of combustion.

There was no indication of grease; but this may be accounted for by reason of the fact that the steam generated was exhausted into the atmosphere and that the feed water was free of oil, except that contained in the river supply.

The appearance of the drums and the tubes conclusively showed that there had not only been an efficient, but a very certain circulation. This was undoubtedly due, in great part, to the large sectional area of downcast tubes. As tersely and epigrammatically expressed by Rear-Admiral Melville, the design and construction of the downcast tubes caused "A Niagara of supply to the lower drum and large lower tubes," thus absolutely insuring circulation.

There were numerous instances, as noted in the remarks of the log of each daily test, where the boiler was subjected to what must be regarded as extremely serious risk, and it was by reason of the fact that the boiler was of excellent design and construction that neither danger nor disablement resulted to any portion of the structure. The feed-water supply failed, through no fault of the boiler, for brief periods, during quite a number of the tests. Special attention is called to the incidents of January 11, 1902, October 25, 1902, and January 5, 1903, wherein will be evidenced the fact that the boiler is not a tender appliance, but one suitable for naval purposes.

Particular attention is called to the data in relation to the efficiency and capacity of the boiler. Estimating the horsepower upon a basis of 16 pounds of water evaporated per hour, the capacity results varied from about 500 to 1,938 horsepower. There was practically but little loss of efficiency when increasing the ash-pit pressure from natural draft to a pressure of 1 inch, for at the latter pressure an efficiency of over 70 per cent was obtained. When forced-draft pressures of 2 and 3 inches were used in the firerooms, the efficiency fell to 60 per cent. When using 3¾-inch pressures in the firerooms, and developing 2¾ times the rated power of the boiler, the efficiency fell to 53 per cent. It was only when an absolutely inadequate number of burners were installed by one inventor, thus preventing a desirable stack temperature being secured, that the boiler showed the minimum efficiency of 49.23 per cent. It is exceedingly doubtful if, under maximum forced-draft conditions, greater evaporative capacity results have ever been secured, in a naval boiler, with so little loss of efficiency as was obtained during some of these capacity tests.

By reason of its efficiency, endurance, and evaporative capacity, this design of boiler should eventually become one of approved type for marine purposes. Its capacity to endure severe forced-draft conditions has been conclusively established, particularly for installation in vessels where there are not exacting limitations as to height. The board believes, however, that high evaporative efficiency can not be expected from any installation of straight water-tube boilers where there are all manner of weight and space restrictions. The high opinion of this boiler is thus recorded after two and a half years' careful observation, during which period there should have developed any inherent weakness either as regards design or construction.

The boiler is well adapted for installation in high-powered armored cruisers and battle ships, and in all marine installations where there are no severe restrictions as to height. It is thus suitable for naval purposes whether considered from any of the following standpoints: Evaporative efficiency, facility for repair or renewal, or for capacity to endure the severe stress to which the boiler would be subjected in times of emergency or in the day of battle.

QUESTION OF FUEL SUPPLY ONLY ONE REMOVE IN IMPORTANCE FROM THAT OF FOOD SUPPLY AS REGARDS OUR ACTUAL NAVAL STRENGTH.

Through a combination of favorable circumstances the steam navy of the United States has never been menaced by the fear of a coal famine. As a matter of fact, neither in the civil war nor in the Spanish-American war were the operations of the Navy of the United States interfered with by a substantial opposing force, and thus the blockades of the South Atlantic and Gulf States, as well as of the Cuban ports, were carried on with the blockading vessels using a minimum amount of coal. There was practically no interruption to the delivery of fuel to any of our fleets during either the civil or Spanish-American wars, and therefore the fuel problem in the conduct of our naval operations has never been accorded the importance that it deserves.

By reason of our acquisition of the Philippines and Hawaiian Islands, as well as by reason of the future responsibility of defending the projected isthmian canal, the scene of our probable future naval operations will be at points less favorable to the United States than has existed in the past. It may be in the Pacific rather than on the Atlantic where our greatest naval battles of the future will be fought. In measuring our naval strength upon that ocean it must ever be kept in mind that the only coal mined in California, Oregon, or Washington is of inferior quality, and that both the Australian and Japanese fuels are far superior to that mined anywhere on the Pacific coast of the American continent.

Practically the only coal, therefore, fit for naval purposes found in countries bordering on the Pacific Ocean is mined outside the United States, and thus the defense of the Hawaiian Islands, if not of certain portions of the California coast, may be greatly dependent upon our ability to use for emergency purposes California oil as a fuel in our ships of war. In consideration of this fact the board is of the opinion that at least one vessel cruising on the Pacific coast should be so arranged as to burn liquid fuel exclusively, and this vessel should be assigned to special experimental work of this nature for an extended period. There should be no attempt to use crude oil as an auxiliary fuel in this coast-defense vessel, but the effort should be boldly made to compel such vessel to rely exclusively upon the oil product.

It will undoubtedly cost considerable money to structurally adapt a war vessel for safely holding a large supply of oil, but the future military necessities of the Pacific coast seem to demand that the experiment should be made. There would be commercial, maritime, and naval advantages accruing by the Navy Department engaging in this work, and one or two years' experiment along this line would be of incalculable benefit in showing to the Navy the military possibilities of utilizing the oil-fuel supply of the Pacific coast for naval purposes.

AN OIL-FUEL INSTALLATION SHOULD BE EFFECTED IN ONE OF THE COAST-DEFENSE MONITORS OF THE PACIFIC SQUADRON.

It is highly probable, unless greater importance is attached to the value of the factors of evaporative efficiency, boiler capacity, steaming radius, and character of fuel supply, that the successful and exclusive use of oil on board an armored cruiser or battle ship can not be brought about for some years. When the time comes that the consumption of coal will be jealously guarded in some such degree as the expenditure of ammunition, then will the expense and difficulty attendant upon the introduction of liquid fuel on board the war ship be recognized in its fullness by naval experts.

For coast-defense vessels, particularly on the Pacific coast, an oil-fuel installation ought to be more easily secured. It is in this direction that practical tests should be made. In case an oil depot were established at Honolulu and one of the coast-defense monitors assigned to the training of men for the engineers' force, it might be possible to effect an oil-fuel installation in one of these monitors whereby the advantages and disadvantages of oil as a fuel for naval purposes could be absolutely ascertained.

In order to secure actual information in regard to the relative merits of various boiler installations, the British Admiralty has placed the services of several war ships at the disposal of a naval-boiler commission. The liquid-fuel problem is of such military importance to the United States Navy that it is not an unreasonable request which asks that one coast-defense vessel on the Pacific coast be immediately fitted for exclusively burning liquid fuel. In addition to the practical benefits that would accrue from carrying on extended oil-fuel experiments in a cruising vessel, the moral effect of initiating such an advance would be an inspiration to all interested in having the Navy Department utilize the immense oil resources that are found on the coast of the Pacific.

AN OIL INSTALLATION SHOULD LIKEWISE BE INSTALLED IN SEVERAL TORPEDO BOATS.

The information and data already secured warrants the immediate installation of oil-fuel appliances on several torpedo boats and torpedo-boat destroyers, to test the adaptability of the water-tube boilers of bent-tube type for using this fuel. The installation should be effected on boats of similar character, so that an earnest but friendly rivalry would be created between the crews of the several vessels. There will come development and success by boldly equipping several boats with different types of installation. The morale of the torpedo-boat flotilla can be strengthened in no better way than by experimenting along this line.

In all probability but one or two of the bent-tube types of boilers fitted in our torpedo boats or destroyers will burn oil efficiently, unless extensive baffling is resorted to in the boilers so as to more efficiently direct the products of combustion among the tubes. Extended tests should be made with torpedo boats to find out the best means of securing an effective baffling, for the information secured will undoubtedly suggest important improvements as regards boiler management and design in the boilers of battle ships.

TESTS CONDUCTED ABSOLUTELY AND EXCLUSIVELY BY A NAVAL PERSONNEL.

All the data recorded in this report was observed either by draftsmen connected with the Bureau of Steam Engineering U. S. Navy Department or by the enlisted personnel of the U. S. torpedo boat *Rodgers*. For ten successive months this torpedo boat was placed at the service of the Liquid Fuel Board, and during that entire period, with the exception of the time given to the routine work of keeping the ship in a state of efficiency, the duty of the crew was exclusively devoted to carrying on the oil-fuel experiments.

The personnel of an efficient torpedo boat in commission must necessarily be representative of ability and integrity. The conduct and work of the crew of the *Rodgers* was thus of exceptional character, and the results secured were due, in great part, to the skill, intelligence, and endurance of the enlisted force of this vessel. These men worked overtime repeatedly with the utmost cheerfulness, and stood ready from the beginning to the end of the tests to run any risk that would contribute to the value of the work.

It was repeatedly the case that fires would be started early in the morning and continued late into the night in order to secure special data or to conduct particular experiments. Time and again, when running under heavy forced-draft pressure, there would occur some temporary disablement of the feed pump, some interference with the feed-water supply, the breaking of a glass water gauge, or the blowing out of a small joint in a steam connection, and such mishaps would sometimes compel the crew to continue firing the boilers when the height of the water in the drum could only be approximately determined. The experience of these men and their absolute confidence in the safety of the boiler thus prevented a single individual from ever leaving his station or neglecting the collection of data. Only those who observed the manner in which these enlisted men performed the work assigned them can have the slightest knowledge of their interest in the tests. Sometimes there would be as many as twenty men actually employed in conducting this experimental work, for the value of the tests depended upon obtaining complete and trustworthy records.

Special attention is called to the fact that the crew of the *Rodgers* operated all the various forms of oil-fuel burners that were experimented with. The board was insistent that every inventor should be responsible for the installation of each appliance. Such inventors were given to understand that any installation which could not be operated by the average engine-room force of seagoing ships, after some preliminary instruction and experience, would not be regarded as adaptable for either naval or maritime purposes. There was not a complaint made by any civilian expert as to the manner in which any liquid-fuel appliance was ever operated by the naval crew. The various burners were thus operated by the same people, and in the determination of the comparative worth of the several appliances this fact should receive consideration. In connection with this matter it need only be stated that probably the most capable and practically experienced fuel expert of the Standard Oil Company repeatedly stated that no crew afloat was more capable of operating a fuel-oil installation than the enlisted force of the *Rodgers*.

VALUABLE SERVICE RENDERED BY VARIOUS ASSISTANTS.

The commanding officer of the U. S. torpedo boat *Rodgers*, Lieut. John Halligan, jr., U. S. N., showed in himself such an example of zeal, efficiency, and professional ability that his personal work and service was to a considerable extent the inspiration that caused the enlisted force of the torpedo boat to secure results that have in many respects never been surpassed in experimental research and investigation.

The board has no hesitation in stating that if it had not been for the untiring, intelligent, executive work of the commanding officer of the U. S. torpedo boat *Rodgers*, no such extended series of tests could have been conducted during the period that the board was engaged in this special work. As typical of his zeal and engineering ability, as well as of his physical and moral courage, it is only necessary to state that in every time of possible danger he was always among the first to open and close the necessary valves to restore normal conditions. Whenever the tests were interfered with by the impairment of some auxiliary, although such tests had been in operation several hours, it was the invariable rule of Lieutenant Halligan to recommence the experiments, even though it subjected his crew to continuous work from early morn until late at night.

The tact and judgment displayed by Lieutenant Halligan in his dealings with numerous inventors was likewise a determining element in having all recognize the fact that while the personal sympathy of the naval officials was with each and every inventor, such sympathy would not stand in the way of rigid consistency and integrity in collecting absolutely correct data and information.

The earnest purpose of this officer to acquaint himself with the manner of conducting experimental investigation and research, and his high administrative efficiency in stationing and directing his crew so that the results of the experiments would commend themselves to all interested in the solution of the oil-fuel problem, is worthy of special recognition by the Department, and the board requests that this deserved tribute to his professional zeal and engineering ability be made a part of his official record.

The board likewise desires officially to express its appreciation of the services rendered by Mr. Harvey D. Williams and Mr. Frank Van Vleck, two fuel-oil experts, who performed service as secretaries of the board. The technical knowledge, executive ability, and power of tabulating original research possessed by Messrs. Williams and Van Vleck were also determining factors in making the series of tests of value to all users of fuel oil. The board greatly regrets that it is not within its power substantially to reward these experts for service performed by them in the conduct of the extended series of experiments. The striking and valuable manner in which the burners have been classified, is, in great part, the personal work of Mr. Van Vleck, and this classification represents years of methodical study and investigation. This practical, concise, and scientific classification should do much in simplifying the construction of burners, thereby reducing their cost while adding to their reliability and ease of operation.

EXPERIMENTAL ENGINEERING RESEARCH WORK OF INESTIMABLE VALUE TO JUNIOR OFFICERS ASSISTING IN THE TESTS.

The naval demands of the future make it compulsory immediately to begin the training of engineering specialists. The result of these tests shows that one of the most effective ways of developing such experts would be to organize a permanent engineering experimental board, whose special province it should be to conduct tests to determine the value of all appliances designed and submitted for use in the naval service. Junior officers of the lines having aptitude and inclination for such work should be detailed as assistants to this board.

Such research work would necessarily be of both theoretical and practical character, and there would therefore be secured upon the part of young officers detailed for such duty progressive professional advance that would eventually fit them for important technical duty.

These assistants should be ordered to accompany various naval technical boards on all journeys of inspection so that they could assist not only in determining the capabilities and efficiencies of the appliances under observation and test, but would have an opportunity to observe the character of the organization and the methods of administration of great industrial plants.

The information secured by members of the Liquid Fuel Board in their visits to various steamers and industrial establishments where oil was used as a fuel was of inestimable value in extending the character of the oil-fuel experiments. The good of the service would have been greatly subserved, however, if a considerable number of young officers had accompanied the board on every inspection tour, and thus had been brought in touch with many of the ablest of the oil-fuel experts in charge of great power plants.

It is undeniably the fact, paradoxical as it may seem, that the larger the technical board appointed to investigate a technical matter, the more knowledge of the subject will each individual member acquire. Where there is an earnest, spirited rivalry upon the part of various individuals to strengthen their position upon debatable points it can be expected that those holding divergent views will ever be on the lookout for special information to maintain their opinion. The final report thus submitted by a board of considerable membership would, in general, be more comprehensive and valuable and command more respect than any report based on the views of a single expert.

The best interests of the service would be attained by having junior officers appointed to associate membership on every important board, for thus there would always be on the active list some officer who would have knowledge of many facts in connection with the investigation of naval matters that were not recorded in official reports. The members of the Liquid Fuel Board were strikingly impressed with the good that would have resulted to the naval service, if from the commencement to the end of the experiments some junior line officers had performed continuous duty in connection with the tests.

CONCLUSIONS DERIVED FROM A COMPARATIVE STUDY OF THE COAL AND OIL TESTS.

In view of the cost incurred and the labor involved in conducting these experiments the manufacturing as well as the maritime world will be most interested in noting the practical conclusions reached. It is hoped that the engineering profession will find much interest in and attach proportionate value to the data collected.

As a result of the extended series of tests the following conclusions have been drawn:

1. That no difficulty should be experienced by an intelligent fire-room force in burning oil in a uniform manner. It need likewise require but little experience upon the part of skilled water tenders to be able to detect, either from the character of the roar or hissing noise or by the color of the flame at different points, an approximate idea both as to evaporative output and efficiency conditions.

2. For general purposes on shore, high-pressure steam is a more satisfactory spraying medium than air. The use of steam, however, as an atomizing agent for naval purposes will undoubtedly require a considerable increase in the size of the evaporating plant, and this must be considered of importance. The necessary increase of the evaporating plant is practically the main objection to the employment of steam as the spraying medium for liquid fuel on board naval and merchant vessels.

3. While the use of steam as a spraying medium will undoubtedly prove most satisfactory for general purposes, the results of the tests show that the consumption of fuel oil can not be forced to as great an extent with steam as the atomizing agent as when highly heated compressed air is used for this purpose. As the war ship is designed to be operated at short notice under the severest forced-draft conditions, the question will have to be considered, whether it is not more advisable to fit air burners that would be found most efficient for the day of battle, rather than effect an installation of steam burners that are most desirable for general cruising. The advantages of air as the best spraying medium for severe forced-draft conditions, is due to the fact that this atomizing agent, after entering the furnace, is a supporter of combustion. With the use of steam as the atomizing agent the rarefied vapor simply displaces a certain portion of air that is requisite for complete combustion. If it were not for the fact that air compressors necessary for supplying an atomizing agent are very bulky and heavy, and require considerable room for their installation, the

question might be considered, whether for war-ship purposes it would not be advantageous to effect an installation whereby either air or steam could be used at will.

4. That in every oil-fuel installation special provision should be made for the removal of the water that will collect from various sources at the bottom of the supply tanks. Even a small amount of water pumped to the burners will interfere with the efficient and satisfactory work of an oil-fuel installation. As it is essential with every boiler plant to secure a uniform if not large output, the annoyance and evil of occasionally pumping water rather than oil to the burners can not be overestimated.

5. That the evaporative efficiency of crude and refined oil is practically the same, no matter from what locality the oil may come. The danger of using crude oil, however, is much greater. As it should not be an expensive matter to build refineries near one of the terminal points of a pipe line, the expense of such refining should not increase to a perceptible degree the cost of such fuel, since the sale of the by-products of crude oil would often pay in great part the expense of distillation.

6. The great benefit of heating the air necessary for effecting combustion can not be doubted.

7. In order to provide a uniform supply of oil to the burners the oil should be heated by some simple means. It can be expected that the burners will be operated much more satisfactorily when oil is thus heated. It being understood that the heating has been carried only to a point well below the temperature of the deposition of the hydrocarbons.

8. Where the use of a liquid-fuel installation is projected, there should be a reserve of burners installed, and these burners should be of a design that would permit rapid examination, thorough overhauling, and easy renewal of special parts by the fireroom force. Careful experiment as well as extended experience have shown that by increasing the number of burners there is not only a more uniform but a more efficient distribution of flame. There is also a minimizing of the blowpipe effect, as well as a marked reduction in the amount of noise in the furnace.

9. That the hygrometric state of the atmosphere has a noticeable influence upon the efficiency and capacity output of boilers.

10. In order to secure in oil-fuel installations more uniformity of conditions in the furnace, and to decrease the noise where air is used as a spraying medium, an air-cushion tank for the oil-supply pump should be installed. Such a tank would break the pulsations of the pump and serve a similar purpose as the regulating air chamber of an ordinary feed pump.

11. In view of the liability of every form of burner to clog, the

necessity of making special provision for straining the oil was emphatically shown. It would be extremely advisable to install a strainer both on the suction and discharge pipes of the oil-feed supply. These strainers should be of a design that would permit rapid examination and renewal, and one patterned after the Macomb type would meet all general requirements.

12. Extended experience in the burning of crude oil will confirm the opinion that the simpler the furnace the greater its efficiency. The erection of brick arches only tends, in many cases, to reduce the volume of space necessary for effecting complete combustion. In Scotch boilers there should be a simple vertical brick lining of the back combustion-chamber wall and a lining of the front end of furnace for about a third of its length.

13. That no design of oil-fuel installation should be permitted for marine purposes which would not permit the renewal within twenty-four hours of all grate and bearing bars, so that a return to coal could be accomplished within a reasonable time in case of failure of oil supply.

14. Where oil is used as a fuel in a Scotch boiler the introduction of retarders in the tubes will undoubtedly increase the evaporative efficiency of the boilers. The use of retarders will prove beneficial by reason of the fact that such devices not only prevent the heated products of combustion from passing too freely through the tubes, but likewise cause a more uniform distribution of these gases in their passage through the tubes to the base of the stack. In thus causing a more uniform and effective heating of the tubes the liability of the end of the tube to be burned is undoubtedly diminished. With oil as a fuel but little soot forms on the heating surfaces of the tubes. Where retarders are not used in large tubes in an oil-fuel installation it is reasonable to presume that a certain portion of the gases of combustion reaches the smokestack without coming into contact with any of the boiler surfaces. Where coal, however, is used as a fuel in a Scotch boiler the resulting coating of the tubes by soot generally reduces their sectional area to a degree sufficient to materially impede the flow of the gases of combustion, and therefore under such conditions the gases reach the base of the stack at a comparatively low temperature. Where oil is properly burned it can be regarded as a fact that the velocity of the flow of the gases is greater than where coal is used, and therefore retarders should be used in the case of fire-tube boilers and increased baffling in the case of water-tube boilers.

15. An important point established has been that the calorimeter openings of water-tube boilers should be less than in the case of the Scotch boiler, whether oil or coal be used as a fuel.

16. That marine firemen are not ill-disposed toward the use of oil. It will be essential, however, particularly for marine work, to secure

intelligent men for the operation of the burners. It will be found that resulting financial economy will ensue by intrusting the management of oil-fuel installations to men of skill and judgment. Cheap labor can not be employed in this work; there will be resulting damage, annoyance, and danger if the operation of oil-fuel burners is assigned to unskilled labor.

17. That the efficiency of oil plants will be primarily dependent upon the character of the installation of fittings and auxiliaries. The form of the burner, so long as it is manufactured in accordance with general well-known principles and all its parts are accessible for overhauling, will play a very small part in extending the use of crude petroleum. The method and character of the installation, however, are all important, and therefore the work of designing and constructing such a plant should only be intrusted to those who have given careful study to the matter and who have had extended practical experience in burning the crude product. Consumers should take special care that they neither purchase appliances that have been untried nor permit the installation to be effected by persons who have had but limited experience in such work.

18. Where crude petroleum has undergone a light refining or distillation no ill effects result to modern steel boilers. From the standpoint of endurance of the boiler the advantage, if any, is with oil. Crude oil, however, by reason of its searching and corrosive effects, has a greater tendency than refined oil to attack the seams and tubes of modern boilers. For marine work, therefore, no crude petroleum should be used, and particularly for ships making long voyages, the fuel oil should undergo some mild distillation before being placed in the tanks.

19. That in the stowing of liquid fuel on board vessels, whether taken on board for fuel purposes or for transportation in bulk, the compartments containing the crude product should be as few as possible, both for reasons of safety and for facility of delivery and discharge.

20. That with the use of oil the forcing of a marine boiler should be much more readily accomplished than with the use of coal.

21. That under severe forced-draft conditions and with water-tube boilers and with the use of oil as a fuel the solution of the smoke question is nearly as remote as ever. Where a limited quantity of oil is burned in a Scotch boiler, however, and retarders are used in the tubes the burning crude petroleum should be smokeless.

22. The value and necessity of installing a series of draft gauges between the ash pan and the base of the stack were conclusively shown. As a result of the study of the draft conditions at different points there were changes made in baffling the gases which were of decided benefit. It is therefore recommended that for experimental purposes a series of draft gauges be fitted to the boilers of several large ships, since

the board is of the opinion that marked gain as to both the efficiency and capacity of naval boilers would be secured by a careful observation and study of the draft condition at various points between ashpan and smokestack.

23. In order to secure for the day of battle increased speed for war ships, naval administrators are justified in demanding of manufacturers of water-tube boilers increased coal consumption per square foot of grate surface. The weight thus saved in the reduction of the number of boilers should be exclusively applied to giving the machinery greater endurance by using heavier boiler linings and casings and more substantial auxiliaries. The space gained in the reduction in the number of boilers should be assigned to providing increased sized firerooms, evaporator rooms, and passageways in the boiler compartments. The fireroom conditions on board the modern battleship could not be much worse, whether viewed from the standpoint of providing for sanitary stokeholds or for an arrangement of firerooms where not only efficient stoking can be carried on, but an installation should be made in which there are adequate facilities for rapidly effecting routine examination and repairs. It is not surprising that there is excessive expenditure as regards cost of repairs, as well as rapid and excessive depreciation, and that the boiler endurance is exceedingly limited when marine steam generators are crowded in the manner in which they are now installed. Under existing fireroom conditions auxiliary feed and bilge pumps are likewise installed directly in the firerooms and even in niches cut out of the bunker compartments. As now arranged the character of the installation of these appliances not only interferes with efficient stoking and repairs to the boilers, but the pumps themselves are constantly under either repairs or examination, due to the dust and grit which settle upon their working parts and thus cause their early renewal. There can be no satisfactory installation of either coal or oil burning appliances until an increase of space is allowed for the operation and preservation of boiler installation.

24. The absolute lack of endurance of both Scotch and mica water-gauge glasses for installation in boilers carrying over 250 pounds pressure and subject to forced-draft usage was conclusively established. Reflex water-gauge glasses should alone be used on boilers which are subject to heavy forced-draft conditions.

25. Practically every form of commercial fire brick that was used in the boiler for the purpose of forming a deflecting arch disintegrated either under the action of the intense heat generated, or due to the action of the acids in the oil or coal. In case any form of arch or bridge wall is essential to the efficient or forced burning of liquid fuel, then special experiments should be conducted to secure a refractory brick that would possess endurance under the severest of forced-draft conditions.

26. For naval installations there should be supplied a fuel oil that will not flash under 175° F. The higher flash point required for naval than for merchant vessels is essential for the following reasons:

(*a*) The war vessel must be kept in readiness to proceed to the Tropics at immediate notice, and the firing of the guns subjects the naval ship to danger conditions to which other types of vessels are not exposed.

(*b*) The fitting of numerous transverse bulkheads and a protective deck in a naval installation, combined with the fact that both machinery and boilers are exceedingly crowded, makes it extremely difficult tó properly ventilate certain compartments, and therefore in war ships it will be necessary to use special precautions both in the stowing and in the handling of oil fuel.

(*c*) The fact that a large number of men must be permanently housed beneath decks on the naval ships will make it difficult to prevent the use of open lights in some of the lower compartments, and thus the danger of using oil as a fuel from this cause will always be greatest in naval vessels.

27. There should be no attempt made to use oil as auxiliary or supplementary to coal. Such an installation is certain to prove unsatisfactory, and the solution of the oil-fuel problem for naval purposes is only delayed by any attempt to inject a limited supply of oil fuel over a bed of incandescent coal. The mechanical feature of the problem having been satisfactorily met, the good of the service requires that any installation attempted should depend alone upon oil as a fuel and not any combination with coal.

28. In maritime construction no oil fuel should be carried in compartments directly beneath the boilers. In case such compartments should ever be used as oil reservoirs, there might be danger of radiated heat from the boilers volatilizing and exploding some of the hydrocarbons of the fuel oil. In case, also, there was any puncturing of the inner bottom, the hot ashes might reach the oil. The possibility of oil also reaching the bilges through improper manipulation of the valves of the manifold boxes is specially liable to happen.

29. The importance and necessity of always possessing a reserve supply of superior fuel were strikingly impressed upon the board, for during both the coal and oil experiments there was resulting delay due to the nondelivery of fuel. Special effort was taken at all times to maintain a reserve supply of coal, but from causes beyond the control of the board shipments of such fuel would be delayed. Particularly was it found difficult to secure hand-picked coal of superior quality, and in one instance such fuel could only be secured within reasonable time by having it shipped at express rates to the experimental plant. The necessity of maintaining at every naval station a large invoice of hand-picked coal of the very best quality, to be utilized for emergency and experimental purposes, was repeatedly emphasized. As for a reserve of coal for war purposes, it is highly

probable that in a contest for the command of the sea an adequate reserve of fuel may be only one remove in importance from the possession of a reserve of ships.

30. In view of the fact that 48 per cent of the world's output of crude petroleum is produced in the United States, and that practically our entire yield is secured from fields which are in pipe-line communication with important maritime and strategic ports, the board considers that a joint commission, representing commercial, manufacturing, maritime, and naval interests, should be authorized by the Congress, whose province it would be to formulate such rules and regulations as would provide for an economical, efficient, enduring, and safe oil-fuel installation. Heretofore the oil-fuel problem has been principally investigated by various individual interests which have sought to secure information along certain lines As a result there has not been obtained that knowledge of the subject which would give to the country at large such development of the use of crude oil as a fuel as would be warranted, considering the natural advantages possessed by the United States in having at its command near great seaports such a large proportionate supply of the world's production of the crude product. Particularly for the development of our commercial interests in the Gulf of Mexico and on the Pacific coast should the work of such a commission have an important influence in extending our prestige and power, whether viewed from a commercial, maritime, or naval standpoint.

The Board would urgently recommend that in all installations of water-tube boilers in naval vessels where economical boiler efficiency has not been obtained, that the commanding officers of such vessels be directed to make some experiments with different arrangement of baffling, and that official report be made of the performance of the boilers under these various conditions. Particularly is it recommended that where there is an excessive coal consumption per indicated horsepower, that the calorimeter nearest the base of the stack be reduced so as to cause complete combustion to be effected amid and not beyond the tubes. The compilation of the data secured from baffling experiments on various types of boilers would undoubtedly suggest important changes whereby the efficiency if not the endurance of such boilers would be increased.

31. The board regards the engineering or mechanical feature of the liquid-fuel problem as having been practically and satisfactorily solved. For manufacturing purposes the financial and supply features are the only hindrances to the use of crude petroleum as a standard fuel. For mercantile purposes the commercial and transportation features of the problem are existing bars which limit the use of oil fuel in merchant ships. For naval purposes there is the additional and serious difficulty to be overcome of providing a satisfactory and safe structural arrangement for carrying an adequate bunker supply.

32. That in the consideration of the problem of attempting to use oil as a fuel for either marine or naval purposes it should be particularly remembered that, by reason of the economic and commercial demands for crude oil for illuminating, lubricating, and other purposes, the available supply of the world's production of crude petroleum that could be used as a fuel would not meet over 3 per cent of the world's demand for coal and other combustibles. For a time, therefore, the effort should be made to use oil fuel only for special purposes in particular localities.

33. The board considers that what will eventually be recognized as the most important result of these extended experiments is the collection of a great mass of trustworthy data concerning the comparative value of coal and oil as a fuel under various conditions. It should be observed that this data was secured with painstaking care and checked at the earliest practicable time after each test. Wherever it was found that discrepancies existed in any experiment the test was repeated, in order to discover if possible the cause of the inconsistency. There has also been secured very complete and trustworthy data in regard to boiler efficiency and capacity.

In conclusion, the board desires to call attention to the fact that these experiments continued uninterruptedly for a period of twenty-eight months, and that for a considerable portion of this time there were no fewer than six commissioned officers giving special consideration to this subject. There were also employed in connection with this duty skilled draftsmen and experts of the Bureau of Steam Engineering, as well as members of the Bureau's clerical staff. For one year there were available for this experimental work the entire crew of the torpedo boat *Rodgers*.

The work represents an immense amount of labor, and as the board has been in correspondence with nearly every interest directly or indirectly concerned with the use of oil as a combustible, it is believed that the report submitted will not only be of value to the Navy Department, but to the manufacturing and mercantile business interests of the nation.

Very respectfully,
John R. Edwards,
Commander, U. S. Navy, Member.
W. M. Parks,
Lieutenant-Commander, U. S. Navy, Member.
F. H. Bailey,
Lieutenant-Commander, U. S. Navy, Member.

To the Chief of the Bureau of Steam Engineering.

Approved August 1, 1903.

Geo. W. Melville,
Rear-Admiral and Engineer-in-Chief, U. S. N.,
Chief of Bureau of Steam Engineering.

INDEX.

Page.
Accidents to experimental boiler, freedom from harmful results 420
Admiral Melville, views on water-tube boilers 54
  Views on requirements exacted by oil on naval vessels 395
Advance burner:
  Tests 21 and 22 144–147
  Tests 39 to 44 180–191
  Tests 67 and 68 236–239
Advantages of an oil-fuel installation 417
Air, compressed, used for atomization (*see* Plan of tests) 102–103
Air compressors 8, 373
Air compressors, *Mariposa* 276
Air, determination of quantity used 13
Air for combustion, Santa Fe burners 90
Air heater for oil service S. S. *Mariposa* 276
Air, regulation of admission to oil furnace 403
Air superheaters S. S. *Mariposa* 283
Air-tight boiler room of the experimental plant 7
Air used in spraying oil 250, 252
Air as a spraying medium, conclusions in regard to 428
Alameda, Oceanic Steamship Company, logs of oil burning 291
American-Hawaiian Steamship Company, oil burning on S. S. *Nebraskan* and *Nevadan* 294
Appliances of oil burning 366
Arrangement of boiler plant for fuel-oil tests 58
Arrangement of experimental plant for coal tests 12
Ashes, weight of 9
Assistants on the staff of fuel-oil board 425
Atmospheric conditions affecting tests 404
Atomization of oil, chemical theory of 316
Atomization of oil without the use of steam or air, by mechanical action 320
Atomizers. (*See* Burners.)
Atomizer burners, type class 342
Austria, coal production of 410
Auxiliaries, consumption of power by, on oil-burning steamers 301
Auxiliaries of experimental boiler 7
Auxiliary appliances for oil burning 366
Auxiliary boiler for supplying steam for atomization 74
Baffles to gain greater oil economy 403
Baffling of gases in water-tube boiler 374
Baffling in water-tube boilers, tests suggested in order to improve the efficiency of coal burning 433
Barometer, average height during trials 243

Page.

Barrus calorimeter 10
Beaumont, Tex., oil 62
Beaumont, Tex., crude oil, analysis 68
Belgium coal production 410
Best, W. N., oil burner 91
  Comparative results 95
  Fitted on torpedo boat *Gwin* 310
  Furnace arrangement 92
  Tests 29 to 81 160–163
  Tests 34 to 38 170–179
Blowers:
  Auxiliary for starting, operated by gasoline 336
  For air, S. S. *City of Everett* 336
  For supply of air to burners 373
Blowers and air compressors of the experimental plant 8
Boiler:
  Auxiliary, supplying steam for atomization 74
  Capacity increase demanded for 432
  Circulation of water in 7
  Data S. S. *Nebraskan* 306
  Evaporative capacity should be greater in water-tube boilers 54
  Experimental, auxiliaries of 7
    Dimensions of 4
    Drums of, dimensions 4–5
    For coal 6
    Form of junction boxes 7
    For oil tests 59
    Smokestack height 5
    Tubes, number and size 4–5
    Heating and grate surface 4
  Hohenstein, horsepower capacity of 420
    Endurance of 419
  Plant for oil tests 58–59
    Arrangement of, for coal 12
  Room air-tightness 7
  Weight of water contained 9
  Land, types of, no experimentation with 383
  Vertical arrangement of, for oil burning 384
  Water-tube, necessity for investigation of 55
    For naval vessels 55
Boilers of the water-tube type, the problem of 54
Booth burners 84
Borneo oil production 411
Borneo oil used on Nederlands-Indies steamer 326
Boston and Maine Railway locomotives burning oil 308
Branch burner 80
  Tests 23 to 28 148–159
Branch system, comparison of tests 82
Brickwork diagrams for use in Scotch boilers 376
Brickwork:
  Disintegration under action of oil 432
  Details for arranging oil-burning furnaces for water-tube boilers 380
  In furnaces, influence of 316–430

Page.
B. T. U., Texas oil ... 68
Bunker, Col. W. M., San Francisco Chamber of Commerce ... 389
Bunkers and tanks for oil, S. S. *City of Everett* ... 336
Bunkers for oil, S. S. *Nebraskan* ... 302
Burners:
  Advance type ... 82
  Booth ... 84
  Centrifugal type, experiments on ... 258
  Conditions for a successful design ... 339
  Depending on gasification of oil ... 364
  Feed tanks ... 371
  Fertility of inventors of ... 338
  Fitton ... 98
  For Russian locomotives, injector type ... 355–358
  For S. S. *Mariposa* ... 276
  F. M. Reed type ... 76
  Harvey system ... 78
  Hayes hydrocarbon ... 70
  Herreschoff design for U. S. S. *Talbot* and *Gwin* ... 355
  Hohenstein-White ... 97
  Influence of the contours of the orifice ... 359
  Injector type, Giffard injector employed ... 365
    Talbot and *Gwin* ... 357
  In reserve should be installed ... 429
  Korting mechanical ... 322
  Lassoe Lovekin ... 269–302
  McDonald type ... 91
  Mechanical, Baku oil fields ... 324
    Board design ... 324
  Mechanical, for oil burning ... 320
    Necessary conditions for ... 324
    S. S. *Tebe*, tests ... 328
    Using Borneo oil ... 326
    With induced draft, tests of ... 334
  Oil City Boiler Works ... 60
    Tests Nos. 10, 11, and 12 ... 75
  Operating on the preliminary gasification of oil not treated in this report ... 338, 340
  Ourgard, Russian locomotive ... 358
  Regulation of oil and air supply to ... 62
  Santa Fe ... 84
  Standard Oil form, *City of Everett* ... 336
  Steam atomizing ... 74
  Systematic classification of ... 338
  The basic type ... 341
  The Branch system ... 80
  Types of, used in tests ... 102
  Urquhart ... 355
  Used on Hoosac Tunnel locomotives ... 309
  Used on Pennsylvania Railroad ... 356
  Using steam not necessarily efficient ... 407
  W. N. Best type ... 91
Burnham, W. D., American-Hawaiian Steamship Company ... 294

Page.

- California oil:
  - Analysis of 69
  - Burning on Santa Fe Railway 84
  - Calorific value 69
  - Production by fields 415
  - Specific gravity 69
  - Used for experimental purposes 389
- Calorific value:
  - California oil 69
  - Texas oil 68
- Calorimeter openings for water-tube boilers should be less 430
- Calorimeter, style used 10
- Capacity of boilers should be greatly increased 432
- Carbon, percentage of, in oils used during tests 68
- Carbon, percentages of, California oil 69
- Carburetor, Harvey system 78
- Carburetors, nonsuccess of 364
- Cargo oil pumps 372
- Chamber burners 342
- Character of oil used in tests 62
- Charcoal and its combustion 313
- Chimney gas analysis 251, 253
- Chemical and mechanical conditions involved in combustion of oil fuel 313
- Chemical analysis of oil used during tests, analysis of Beaumont oil 68
- Chemist, New York Navy-Yard, oil analysis 68
- Circulation of water, dependent on baffling 374
- Circulation of water in the Hohenstein boiler 420
- Circulation of water in experimental boiler 7
- Classification of oil burners 338
- Coal, analysis of 10
- Coal and oil as fuel, relative value 390
- Coal and oil tests, the final conclusions 428
- Coal and oil, world's production of 409
- Coal compared with oil as fuel 417
- Coal:
  - Grate bars for 377, 381, 430
  - Measurement of 8
  - Method of weighing 9
  - Quality used 10
  - Shortage of, on the Pacific 422
- Coal tests:
  - Arrangement of boiler for 6
  - Data secured 13
  - Tables of 16–53
- Coast-defense monitors on Pacific, desirability of fitting for oil burning 423
- Cofferdams as security against leakage, American-Hawaiian Company 295
- Cofferdams, construction of S. S. *Nebraskan* 305
- Coking up of oil-burning apparatus when attempting gasification of oil 364
- Combination air and steam burner, Reed 76
- Combustion space required by liquid fuel 316
- Combustion, mechanics of, as applied to oil fuel 313
- Comparative results:
  - Best burner 95
  - Oil City burner 96, 100

Page.
Comparative results of tests of Advance burner 84
Comparison of coal and oil as fuel 390
Comparison of coal and oil trials using Korting mechanical burners 334
Comparison of conditions, locomotive and torpedo-boat work 309
Comparison of oil fuel by volume or by weight 417
Comparison of oil with coal as fuel 417
Comparison of results, Santa Fe burners 88
Comparison, eastern burners with eastern oil, western burners with western oil 97
Composition plugs of Hohenstein boiler 7
Compressed air used for atomization 76
Compressors, air 8
Conduct of tests by the board 424
Conclusions derived from the oil and coal tests 428
Conclusions on centrifugal burners 264
Confirmation of oil results by other tests 385
Consumption of power by auxiliaries, oil-burning ships 301
Crew comparison, oil-burning against coal-burning steamers 301
Crew, S. S. *Mariposa*, relative, with coal and oil 272–281
Crew of the U. S. S. *Rodgers*, constituting the experimental staff 424
Crude petroleum. (*See* Oil.)
Date of oil trials 102, 242
Davie safety lamps, use with oil installations 406
Deane, C. T., Dr., secretary California Petroleum Miners Association 389
Diagrams of furnace arrangements 376
Disk burners 258
Double bottoms:
  Carrying of oil in 406
  No oil to be carried beneath engine and boiler space 406, 433
Draft gauge:
  Diagrams for coal 14
  Diagrams of oil tests 63–65
Draft gauges 11
  Importance of installing a number of 15
  Necessity for 431
Draft openings into furnace, oil trials 246
Drilling of holes instead of punching, for oil tank construction 406
Drooling burners 342
Dudley, Dr. C. B., superintendent of tests, Pennsylvania Railway Company 355
Duration of trials in hours 102–242
Economical results from tests 250, 252
Efficiency of oil determined by tests 255, 257
Endurance of the Hohenstein boiler 419
Endurance test of one hundred and sixteen hours 66, 114
Evaporative capacity under forced draft 420
Evaporative capacity should be greater in water tube boilers 54
Evaporation of water during tests 251, 253
Evaporative efficiency:
  Advance burners 84
  Best burner 95
  Branch burners 82
  Harvey & Best burners 80
  Oil City Boiler Works burner 96–100
  Santa Fe burners 89

Page.
Evaporative efficiency of oils 429
Evaporative efficiency, oil compared with coal 417
Expansion trunk, S. S. *Mariposa* 275
Expansion trunks, S. S. *Nebraskan* 306
Experimental boiler, dimensions (*see also* Boiler) 4–5
Experimental boiler for oil tests 59
Experimental boiler plant for fuel oil tests 58
Experimental plant, arrangement of, for coal burning 12
Experiments on centrifugal burners 258
Explosive vapors from tanks 396
Feed pumps 8
Feed tanks for burners 371
Feed tanks for oil, S. S. *Mariposa* 275
Feed water during experiments 419
Feed water, measurement of 8
Filters or strainers for oil 366
Fire brick, disintegration of, under action of oil 432
Firemen not ill disposed toward oil 430
Fire point, Texas oil 68–69
Fitton Burner 98
Flash point for naval fuel oil 432
Flash point, Texas oil 68–69
Flue gases 11
France, coal production 410
Forced draft conditions, conclusions of 428
Forced draft conditions and the smoke 398
Forced draft efficiency on the Hohenstein boiler 420
Forcing of marine boilers 431
Formation of a mechanical spray 321
Fuel oil burners. (*See* Burners.)
Fuel oil tests:
  Arrangement of boiler for 59
  Summary of 242
Fuel, relative production of, in the world 409
Fuel supply, one remove in importance from food supply 422
Funnels, sighting of S. S. *Mariposa* 282
Furnace arrangement:
  Best burner 92
  Harvey system 78
  Hayes burner 72
  S. S. *Mariposa* 279
  S. S. *Nebraskan* 303, 306
Furnace, arrangement of, for vertical boiler 384
Furnace arrangements for oil burning, S. S. *City of Everett* 336
Furnace arrangements:
  Branch system 81
  Hoosac tunnnel locomotives 308
  Necessity of proper design of brickwork 375
  Oil City burners 99
  Santa Fe burners 86
Furnace brickwork 430
Furnace construction 373
Furnace details, mechanical spray burners S. S. *Tebe* 331

Page.
Furnace forms for water tube boilers 379
Furnace men required rather than stokers 301
Furnaces, land boiler types, no experimentation with 383
Furnaces, proper admission of air for oil burning 403
Gasification of oil:
  Non success of 364
  In the Harvey system 78
Gage glasses, increased life demanded 432
Gages:
  Draft 11
  Pressure 11
Gas and chimney analysis 251–253
Gasoline engine driving auxiliary blower S. S. *City of Everett* 336
Gibson, Robert W., Best Burner Company 91
Germany, Coal production 410
  Oil production 411
Getting up steam under oil 61
Goode, C. B., Santa Fe Railway Company 84
Grate bars for coal 377, 381, 430
Great Britain coal production 410
Grundell & Tucker burner S. S. *Mariposa* 276
Gwin, torpedo boat, fitted with Best burners 310
Halligan, John, jr., Lieut. U. S. Navy, officer of tests 66, 425
Harvey arrangement of furnace details for burning oil 78
Harvey process for oil burning 78
Harvey burner, tests 32 and 33 166–169
Harvey system, comparison of results 80
Hawaiian Islands, as a fueling port 422
Hayes burner:
  Arrangement of furnace installation 72
  Test No. 9 120
Hayes Hydrocarbon burner 70
Heaters for oil 369
Heating of air used for atomizing 373
Heat value, 1 pound of oil from chemical analysis 255–257
Henderson, George R., superintendent of motive power, Santa Fe Railway 84
Hoffman, W. D., fuel-oil representative Standard Oil Company 308
Hohenstein boiler:
  Capacity of 420
  Baffling of 374
  Dimensions (*see also* Boiler) 4–5
  Endurance of 419
Hohenstein boiler plant for fuel oil tests 58
Hohenstein boiler plant, coal burning 12
Hohenstein-White oil burner 97
Hoosac Tunnel oil-burning locomotives 308
Horsepower of the Hohenstein boiler 420
Howden hot draft in effecting economy 385
Howden hot draft system as applied to oil burning, American Hawaiian Line 296
Humidity of atmosphere as affecting capacity and economy 404
Humidity, degree of 243
Hydrocarbons deposited in burners 340
Hydrogen, percentages of, California oil 69
Hygrometric conditions affect efficiency 404

Page.

Injector burner:
- Pennsylvania Railroad........ 356
- Russian locomotive........ 358
- *Talbot* and *Gwin*........ 357

Injector burners, types of........ 343
Insurance risks, oil-burning steamers *Nebraskan* and *Nevadan*........ 294
Introduction to report........ 3
Isherwood, engineer in chief, U. S. Navy, views on gasification of oil........ 364
Johnson, warrant machinist, U. S. Navy........ 66
Junction boxes of Hohenstein boiler........ 7
Junior offices of the Navy, value of experimental work to........ 426
Knots made per ton of oil, S. S. *Mariposa*........ 286
Knots made per barrel of oil, S. S. *Mariposa*........ 286
Korting mechanical burner........ 322
Korting burner tests compared with coal burning........ 334
Korting burners, S. S. *Tebe* tests, mechanical spray burners........ 328
Korting burners with induced draft........ 334
Land conditions not applicable to marine work........ 388
Land types of boilers, no tests with........ 383
Lassoe Lovekin burner, details of........ 269, 302
Lassoe, superintending engineer, American-Hawaiian Steamship Company... 295
Launch boilers, oil-burning furnace for........ 384
Lincoln, G. S., Lieut., U. S. Navy........ 66
Liquid fuel burners. (*See* Burners.)

Liquid fuel tests:
- Arrangement of boiler for........ 59
- Summary of........ 242

Lloyds rules for tanks, bulkheads, etc........ 406
Locomotive and torpedo-boat burners compared........ 308
Locomotive burner, Russian........ 358
Locomotive burners, Santa Fe........ 85
Locomotives burning oil........ 308
Log of S. S. *Mariposa*, burning oil........ 286
Long voyages under oil burning, American-Hawaiian Steamship Company... 294
Loss of fresh water due to steam atomization........ 76

Lovekin:
- Superintendent New York Shipbuilding Company........ 269
- Oil-burning experiments........ 268-302

Low-pressure air by blowers for use of burners........ 373
Low-pressure air burners Lassoe Lovekin, S. S. *Nebraskan*........ 269, 302
Low-pressure air burners, Standard Oil Company........ 336
Macomb strainers........ 366
Management of the tests open to public........ 402
Mariposa steamship, oil-burning vessel........ 271
McDonald burners........ 91
- Test 55........ 212-213

Measurement of coal, water, and refuse........ 8
Mechanical atomization of oil by centrifugal means........ 258
Mechanical burners for oil........ 320
Mechanical burners using Borneo oil........ 326
Mechanical spray burners, furnace details........ 331
Mechanics of combustion, relating to oil fuel........ 313
Melville, G. W., Admiral, views on requirements exacted by oil on naval vessels........ 394

Page.
Melville, Rear-Admiral, views on water-tube boiler 54
Mirror used for observation of smoke 62
Muddy water in tests 67
Naval boilers, views of Admiral Melville 55
Naval disadvantage of the smoke nuisance 398
Naval limitations in the use of oil 394, 433
Naval needs of fuel on the Pacific 422
Naval research properly conducted by persons within the Navy 407
Naval vessels on the Pacific coast should be fitted for oil burning 423
Naval vessels boiler capacity should be greatly increased 432
Navy launch boiler, oil burning furnace for 384
Nebraskan, American Hawaiian Line, use of oil 294
Nederlands steamer—
  Hasenwind, oil burning 323
  Brouwer, oil burning 327
  Of East Indies, oil burning 326
Nevadan, American Hawaiian Line, use of oil 294
New York market prices of oil compared 392
Nitrogen, percentages of, California oil 69
Noise in oil fuel plants 429
Noise produced by injector burners 359
Noise produced by inlet of air 403
Oceanic Steamship Company, S. S. *Alameda*, log 291
Oceanic Steamship Company's steamer *Mariposa* 271
Officers, junior, of the Navy, value of testing work to 426
Officers of tests 66
Oil and air pressures should be interrupted when pressure of either ceases 371
Oil and air supply of burners, regulation of 62
Oil analysis, S. S. *Mariposa's* trips 278
Oil bunkers, arrangement of, S. S. *Nebraskan* 302
Oil-bunker tanks, S. S. *Mariposa* 272
Oil-burning apparatus in duplicate, S. S. *Nebraskan* 302
Oil-burning furnaces in water-tube boilers 379
Oil burners, types of. (*See* Burners.)
Oil burned in combination with coal not desirable 433
Oil-burning tests conducted, thirty years since Charleston Navy-Yard 364
Oil, California, analysis of 69
Oil-cargo pumps 372
Oil City Boiler Works' burner 60, 95
  Tests 1 to 8, 10 to 12, 15 to 20, 45, 56 to 66 69
Oil City burners, furnace arrangements 99
Oil City Boiler Works' experts present at test 67
Oil, character of, used in the experiments 389
Oil and coal, relative production of the world 409
Oil and coal as fuel, relative value 390
Oil and coal tests, the final conclusions 428
Oil compared with coal as fuel 417
Oil consumption during tests 250, 252
Oils, distillation of, percentages passed over 68
Oils, flash-point for, when intended for naval use 432
Oil-fuel installation, advantages of 417
Oil fuel not to be carried in double bottoms beneath engine and boiler spaces 406, 433
Oil-fuel flame, nature and properties of 313
Oil-fuel installations for locomotives and torpedo boats similar in their needs 308

Page.
Oil-fuel installation S. S. *City of Everett*.... 336
Oil-fuel installation of S. S. *Nevadan* and *Nebraskan*.... 294
Oil-fuel, mechanics of combustion.... 313
Oil-fuel tests, arrangement of boiler for.... 59
Oil fuel per hour during tests.... 250, 252
Oil fuel, use of, as such, commercially limited.... 435
Oil heaters.... 369
Oil-pressure regulators.... 371
Oil prices compared.... 392
Oil production of the United States available for fuel.... 416
Oil-service pumps, S. S. *Mariposa*.... 276
Oil strainers.... 366
Oil tests:
    Arrangement of boiler for.... 59
    General plan of.... 102
    Open to the public.... 402
    Summary of.... 242
Oil used in tests, Texas, secured from Standard Oil Company.... 62
Oil used in tests, method of weighing.... 61
Oil used, character of.... 62
Oil vapors, protection against.... 396
Orificial spraying.... 359
Ourgard Russian locomotive burner.... 358
Oxygen, percentage of, in oils used during tests.... 68
Oxygen, percentages of, California oil.... 69
Pacific Ocean, naval needs as regards fuel.... 422
Pennsylvania oil prices compared.... 392
Pennsylvania Railroad injector burner.... 356
Percentage of oil to the world's fuel supply.... 409
Percentage of steam required for atomization.... 74
Personnel of naval experimental tests.... 407
Personnel of the naval tests.... 424
Petroleum. (*See* Oil.)
Petroleum burners. (*See* Burners.)
Petroleum, fire point.... 68, 69
Petroleum, flash point.... 68, 69
Petroleum residuum used in tests.... 69
Petroleum, surface tension of.... 317
Petroleum, Texas, analysis.... 68, 69
Pipe line certificates compared in price.... 392
Piping for oil tanks on naval vessels.... 396
Plan of oil tests.... 102
Preliminary or unofficial trials conducted.... 388, 419
Preliminary run before endurance test.... 67
Prices of oil compared.... 391
Prices of coal and oil compared.... 391
Prices of Pennsylvania oil compared.... 392
Projector burners, types of.... 343
Potomac River water used during tests.... 67
Preliminary or unofficial trials.... 419
Preliminary or unofficial tests on oil.... 388
Pressure gages, arrangement of.... 11
Prevention of smoke.... 399

Page.
Problem of the water-tube boiler 54
Procter, A. M., Lieut., U. S. Navy 66
Production of oil by countries and fields 410
Proportion of oil to the world's fuel supply 409
Pumps, feed 8
Pumps for cargo oil 372
Pyrometers used 62
Quality of coal used 10
Recommendations for a board to determine proper conditions to govern use of oil in Navy 433
Reduction of oil burners to simpler classification 338
Reed burner, tests 13 and 14 129–131
Reed combined air and steam burner 76
Regulations of oil and air, S. S. *Mariposa* 282
Regulators for maintaining oil pressures 371
Regulation of oil and air supply to burners 62
Relative production of the world's fuel 409
Relative production of coal and oil of world 409
Relative value of coal and oil as fuel 390
Report Capt. H. N. Stevenson, oil burning, S. S. *Mariposa* 271
Report of Lieut. Commander Ward Winchell, S. S. *Mariposa* 280
Reserve supplies of oil fuel for naval purposes 433
Results of the experimental work of the board 428
Retarder, final conclusions 430
Retarders, theoretical advantages of 317
Retarders reducing smokestack temperatures 303
Riveting for oil tanks 372
Rodgers, U. S. S. torpedo boat, testing staff for Liquid Fuel Board 424
Root blower, supplying air for burners 8, 303
Rowe, warrant machinist, U. S. Navy 66
Russia:
  Coal production 410
  Oil production 411
Safety lamps, use of 406
Santa Fe Railway Company 84
Santa Fe burners 84
  Air for combustion 90
  Tests 46 to 54 194–211
Schreiber, warrant machinist, U. S. Navy 66
Scotch marine boiler furnace forms 375
Separation of water 369
Settling tanks for oil, S. S. *Mariposa* 274
Smoke conditions with oil 431
Smoke nuisance 398
Smoke nuisance in torpedo boat oil burning 310
Smoke, observation of, by mirror 62
Smoke pipe temperatures, reduction of temperature of 430
Smokestack temperatures, S. S. *Nebraskan* reduced by retarders 303
Smothering pipes for oil cargo holds or bunkers 396
Specific gravity:
  California oil 69
  Texas oil 68
  Residuum used 69

Page.

- Spraying oil:
  - By air or steam. (*See* Burners.)
  - By centrifugal force 258
  - By mechanical burners 320
  - The mechanics of.......... 316
- Spraying by use of steam or air, conclusions.......... 428
- Spraying by means of the orificial contours.......... 359
- Staff of the experimental board.......... 424
- Standard oil steamer *City of Everett* trials.......... 336
- Standard Oil Company, oil secured from 62
- Steam atomizing burners.......... 74
- Steam burners not necessarily efficient.......... 407
- Steam as a spraying medium, conclusions 428
- Steam, character of evaporated 10
- Steam, method of raising.......... 61
- Steam pivot centrifugal burner 260
- Steam required for atomization 74
- Steam turbine burners 258
- Steam used in spraying oil 250, 252
- S. S. *Alameda*, log of, using oil 291
- S. S. *Brouwer* using mechanical burners.......... 326
- S. S. *City of Everett*, oil-burner operations.......... 336
- S. S. *Mariposa:*
  - General logs of trips burning oil.......... 286
  - Report on oil-burning installation 270
- S. S. *Nebraskan:*
  - Boiler data.......... 306
  - Oil-burning trips 294
  - Summary of logs, oil burning.......... 298
- S. S. *Nevadan*, summary of logs, oil burning.......... 298
- S. S. *Tebe*, Italian Navigation Company, oil-burning installation.......... 328
- Steele, warrant machinist, U. S. Navy 66
- Stevenson, H. N., captain, U. S. Navy, report on oil burning, steamer *Mariposa*. 271
- Stokers not ill disposed toward oil.......... 430
- Storage of oil on shipboard.......... 372, 405
- Strainers for oil, difficulties with:
  - S. S. *Mariposa*.......... 283
  - S. S. *Tebe*.......... 332
- Strainers, needs for.......... 328, 366, 430
- Structural forms of the—
  - Atomizer burner 347
  - Chamber burner 350
  - Drooling burner.......... 343
  - Injector burners.......... 353
- Structural requirements, oil supply to naval vessels.......... 394
- Suction pipes for oil tanks.......... 370
- Sulphur in crude oil used in tests.......... 68
- Sulphur, percentages of, California oil 69
- Summary of coal tests 50–53
- Summary of oil tests.......... 242
- Summary of logs of oil-burning ships *Nebraskan* and *Nevadan*.......... 298
- Summary of trips of S. S. *Mariposa* 286
- Superheating of oil and air, Branch system.......... 80
- Surface tension of oil films 317

Page.

Swash plates in oil bunkers 406
Tank construction 405
Tank construction for oil on naval vessels 395
Tanks for measuring of water 8
Tanks for oil, thickness of 405
Tank suction pipes for oil 370
Tank ventilation 372
Temperatures:
  Average during trials 246
  In combustion chamber and smokestack 62
  Of flue gases 11
  In smoke stacks reduced by retarders 303
Tests on oil, general arrangement of the official data 102
Tests of coal 16–53
Tests of centrifugal burners 258
Test for endurance, one hundred and sixteen hours 66, 114
Tests of oil fuel on S. S. *Tebe*, Italian steamer 328
Tests on oil burning, additional to those here given, confirmatory of the U. S. Naval Board data 385
Tests on oil open to the public 402
Testing staff of the Liquid Fuel Board 424
Texas oil:
  Analysis 68
  Prices 391
  Specific gravity 68
  Used for experimental purposes 62, 389
Thermal efficiency not increased by use of steam burners 407
Theory of combustion with oil fuel 313
Transportation features in the supply of oil 394
Trial trips, S. S. *Mariposa* 277
Torpedo boats, desirability of fitting oil burning on 423
Torpedo boat *Gwin:*
  Crew from, used during test 66
  Fitted with W. N. Best burners 310
Torpedo boat *Rodgers*, crew from, used during test 66
Turbine steam burners 258
Types of orificial spraying 360
United States:
  Coal production 410
  Oil production 411
  Geological Survey, tables of coal and oil production of the world 409
  Naval torpedo boats, desirability of fitting, for use of oil burning 423
  Shortage of coal on Pacific coast 422
Unofficial or preliminary tests on oil 388, 419
Uptake temperatures, reduction of 430
Urquhart, superintendent of motive power, Trans-Siberian Railway 355
Value of oil produced by countries and fields 414
Van Vleck, Frank, technical secretary of board 426
Vaporization of a liquid fuel, chemical theory of 316
Vaporization point, Texas oil 69
Vapors from oil, necessity for removal 372
Ventilating heads or cowls 372
Ventilation of oil bunkers, S. S. *Mariposa* 274

Page.

Ventilation of oil tanks ... 372

Vertical boiler, oil-burning furnace for ... 384

Volume of combustion space requisite in oil burning ... 316

Wallsend Slipway and Engineering Company, tests of mechanical burners ... 334

Ward boiler, oil-burning furnace for ... 384

Warner, J. B., Hartford Steam Boiler Inspection & Insurance Co ... 405

Water:

- Character of circulation in experimental boiler ... 7
- Drainage of, from tank bottoms ... 429
- Evaporated during tests ... 250–251, 252–253
- Gage glasses, increased life demanded ... 432
- Separators ... 369
- Tube boilers of the bent-tube type, desirability for further tests on ... 423
- Tube boilers, furnace designs for burning oil ... 379
- Tube boiler, Hohenstein, details of ... 4
- Tube-boiler problem ... 54
- Weight of, contained in boiler ... 9

Weather, state of, during oil trials ... 242

Weight of ashes ... 9

Weight of water contained in boiler ... 9

Weighing oil used in tests ... 61

Westinghouse air-brake type of compressors ... 373

Whaleback steamer *City of Everett*, oil-burning plant ... 336

Whirling disc burners ... 258

White-Hohenstein oil burner ... 97

White, William Russel, lieutenant, U. S. Navy ... 66

Williams centrifugal burners ... 258

Williams, Harvey D., technical secretary, Naval Liquid Fuel Board ... 258, 426

Winchell, Ward, lieutenant-commander, U. S. Navy ... 271, 280

Wire gauze in ventilating cowls ... 372

World's relative production of coal and oil ... 409

O

89077454783

B89077454783A

ENGINEERING
LIBRARY

89077454783

b89077454783a